METAMORPHOSES OF THE PROCESSIONARY MOTH (*Cnethocampa processione*) AND OF CALOSOMA SYCOPHANTA.

CASSELL'S

NATURAL HISTORY.

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HYMENOPTERA (*concluded*).

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NEUROPTERA.

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LEPIDOPTERA.

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DIPTERA.

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FAMILY ICHNEUMONIDÆ.

THE term Entomophaga, or "Insect-eaters," does not strictly apply to all the insects included in the tribe so named by entomologists, but so great a majority of them are parasitic in the larva state upon other insects, that the name is a perfectly admissible one. The group may be at once distinguished by the possession of a petiolate abdomen and two-ringed trochanters.

The largest and most important family of this tribe is undoubtedly that of the Ichneumonidæ,

the larvæ of which are all parasitic. In this family, which includes the largest species of the group, we find a great variety of characters, but the insects composing it have the antennæ thread-like or bristle-like, generally long and many-jointed, and the wings with from one to three complete submarginal cells. The body is long and thin, and the abdomen shows at most seven segments. The ovipositor issues from the extremity of the abdomen of the female.

This enormous family of insects is at the same time one of the most difficult to study systematically, and although we know that the number of species must be very great, it is almost impossible to estimate what it may be. It has been calculated that there are not less than 4,000 to 5,000 known species of Ichneumons, but the data are very untrustworthy. They occur in all parts of the world, and their importance in the economy of nature is very great. The females deposit their eggs in or upon the bodies of other insects, especially the larvæ of Lepidoptera and plant-eating Beetles. The larvæ hatched from these eggs feed upon the substance of their host, avoiding the vital parts, so that the unfortunate animal goes on assimilating food for the benefit of the parasites dwelling within him until he completes his term of larval existence, and sometimes even attains the perfect state; but sooner or later the parasites either break out of the body of their host, or spin their cocoons within it, with a result that in either case is equally fatal. No stage of the insect's life is safe from these active enemies; they attack all, from the egg to the imago, but the larvæ receive most of their attention. A great number of the species are confined to particular families of insects in the choice of their victims, while others infest only particular genera or even species, and the charge of parasites introduced into the body of an individual host is always proportionate to the relative sizes of host and parasite. Thus the eggs of insects are attacked only by the smallest species of Ichneumons, and only a single egg is deposited in them; the larger Ichneumons also frequently place only one egg in the caterpillars or other larvæ which they attack, and the Ichneumon larva then spins its cocoon within the emptied pupa case of its victim. On the other hand, many small species deposit their eggs in large caterpillars or other larvæ, and then the number of eggs is proportioned to the size of the host, and the Ichneumon larvæ either fill up the empty cocoon with a mass of close-packed cocoons, or break out of the infested larva as it is preparing to change, and spin their cocoons separately around it. But perhaps the most remarkable circumstance connected with this parasitism is that the parasites are themselves subject to be attacked by parasites belonging either to this family or to one of the succeeding ones, the females of these having the instinct to recognise the presence within the host of a parasitic larva, and possessing the art of passing their eggs through the integuments of the former into the latter. We have thus in the history of these insects a series of checks and counterchecks of the most astonishing complexity. As the Ichneumon larva uses up all the material it derives from its host in building up its own body, it naturally grows pretty rapidly, and the host may perhaps be stimulated to increased assimilation by the presence of hungry parasites in its interior. The respiration of the latter is provided for in a curious way; the principal tracheal stems open at the hinder extremity of the body, and this is brought into connection with one of the stigmata of the host, thus opening a free communication with the external air.

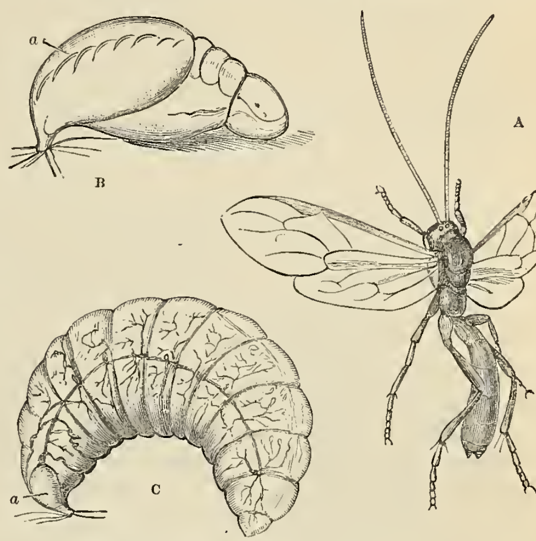
WING OF ICHNEUMON.

The development of the ovipositor is very different in the females of different genera and species of Ichneumons, and this stands in direct connection with their habits. In the females of some forms the ovipositor scarcely projects from the extremity of the abdomen, whilst others have a long, bristle-like organ two or three times the length of the body, and between these two extremes every gradation occurs. The short ovipositors are possessed by species which deposit their eggs in or upon easily accessible larvæ; the long ones characterise those which seek concealed larvæ, such as the grubs of wood-eating Beetles.

The species of *Ophion*, *Paniscus*, and some allied genera which have long antennæ, only two submarginal cells, a compressed abdomen, and a very short ovipositor, possess a very curious history. They deposit small stalked eggs (see figure), much resembling little seeds, upon the surface of various caterpillars, and these eggs adhere to the skin of the caterpillars by little hooks at the extremity of the stalk. After a time the egg splits into two valves, from between which a minute grub issues, and proceeds at once to push its head through the integuments of the caterpillar, so as to feed upon the

contents of its body. In some cases the Ichneumon larva makes its way within the body of its host, and becomes an internal parasite ; in others it remains permanently on the outside, its hinder extremity being always enclosed between the valves of the egg-shell, and then, its body being very translucent, the transfer of the substance of the host to the parasite may be observed going on very actively.

In the genus *Evania* and its allies we find a very curious arrangement. The abdomen, instead of springing from the back of the thorax immediately above the hinder coxæ, is lifted up, so that its thin petiole is attached just beneath the back of the metanotum. In *Evania* the abdomen is so small as to appear only like an appendage to the thorax; hence the best-known species has been named *E. appendigaster*. It is a small black insect found in the South of Europe and in all tropical countries. It is parasitic upon Cockroaches. An allied British genus (*Fœnus*) has a very long, slender abdomen, and the prothorax produced into a thin neck. *Fœnus jaculator* is a not uncommon species found haunting the burrows of Crabronidæ, upon which it is probably parasitic. The American genus *Pelecinus*, which has been placed with these forms, although its abdomen is attached in the ordinary position, is remarkable for the very disproportionate length and slenderness of the abdomen in the females. *P. polycerator*, which inhabits both North and South America, attains a length of two inches, five-sixths of which consist of abdomen.



PANISCUS VIRGATUS (A), WITH YOUNG (B) AND OLD (C) LARVÆ. *a*, EGG-SHELL.

In the group of typical Ichneumonidæ, we have already referred to the genera *Ophion* and *Paniscus*, and their peculiar habits in the larva state. Many species of these, and allied genera, in which the abdomen is compressed, and the ovipositor short, are to be met with in Britain. In the genus *Ichneumon* proper, and many others allied to it, the ovipositor is also short, but the abdomen is either depressed or convex above. *Cryptus* has a nearly ovate abdomen and a projecting ovipositor ; whilst in *Pimpla* and a number of other allied genera we find a long ovipositor for attacking concealed larvæ. A species of *Pimpla* (*P. manifestator*) is figured on p. 1. It is a handsome black insect with red legs. The body measures thirteen lines, and the ovipositor seventeen lines in length, so that the whole insect is two inches and a quarter long. Many exotic species are larger, and have still longer ovipositors. In these insects the sheaths of the ovipositor serve as guides for the instrument itself when penetrating into hard bodies.

A large group, chiefly consisting of small species, is that of the Braconides, which differ from the typical Ichneumons in having the first submarginal cell more or less separated from the discoidal cell, and only one recurrent nervure, instead of two. Some of them have the ovipositor projecting ; in others it is concealed. The abdomen is generally more or less ovate. The typical genus *Bracon* includes an immense number of species, and these are among the largest of the group. One of the best-known species is the little *Microgaster glomeratus*, which is parasitic upon the caterpillars of the common White Butterflies. The larvæ burst forth from the body of the caterpillar when it is ready to change, and form round its empty skin a little heap of yellowish cocoons. *Aphidius* and some nearly allied genera include minute species which are parasitic upon Aphides.

FAMILY PROCTOTRUPIDÆ.

A vast multitude of small parasites form this family, distinguished from the preceding by the structure of the fore wings, which have a distinct stigma on the anterior margin, but no complete cells, the veins being generally reduced to a few hardly perceptible longitudinal ones. In a great many species the wings are altogether wanting. The antennæ vary in structure, being either straight or bent, and they usually consist of fourteen or fifteen joints, but sometimes only of eight. The eyes

are not notched, the ocelli are indistinct, the prothorax is produced on each side as far as the insertion of the fore wings, and the abdomen consists of from five to seven rings, with the ovipositor issuing from its extremity. The hinder thighs are generally not thickened.

TELEAS LÆVIUSCULUS, MAGNIFIED.

The great majority of the species of this family are minute black insects, with opaque, hairy, whitish wings, and often, notwithstanding their minuteness, of exceedingly elegant form. Like the Ichneumonidæ, they are parasitic in their habits, the females depositing their eggs in the eggs and larvæ of other insects, and attacking especially the larvæ of the Tipulidæ, Aphides, Gall Flies, and Lepidoptera. The species are spread over the whole earth, and their number is incalculable in the present state of our knowledge. It may be observed, however, that over 150 genera have been established for the German forms alone. The larvæ, when full fed, spin a little cocoon for their protection during the pupa stage. As an example of this family we figure a small species (*Teleas læviusculus*), which deposits its eggs in those of certain Lepidoptera. It is a minute shining black insect, with brownish legs. The species of the genus *Mymar* have slender wings, terminating in a broad expansion like a battledore. The expanded part is fringed with long hairs.

FAMILY CHALCIDIDÆ.

This is another large family of parasites distinguished from the preceding by several characters. The antennæ are always short and kneed, and consist of from six to fourteen joints; the fore wings have a costal vein, but scarcely any indication of others; the prothorax is not produced at the sides to the base of the wings; the hinder thighs are thickened, so that the hind legs are fitted for jumping; and the ovipositor, which may be either long or short, issues from the ventral surface of the abdomen at some distance from its apex. The abdomen consists of six segments in the females and of seven in the males. The species are excessively numerous, as may be judged from the fact that in England alone some 1,200 species have been recorded.

These insects, which are nearly all of minute size, species of half an inch long being giants among them, are parasites in other insects of the most various orders, and attack them in all stages of their existence, from the egg to the pupa. In all their habits they resemble the smaller Ichneumonidæ, but among them we find the great majority of the species which are parasitic upon the parasites of other insects. They generally have the abdomen more or less compressed, and their surface usually shows metallic colours, but this is subject to exceptions, especially among some of the larger species. Thus the South European *Leucospis dorsigera*, which is parasitic in the nests of Bees, and measures four or five lines in length, is black, with bands on the prothorax and scutellum, three bands on the abdomen, the shaft of the antennæ and the legs yellow; and *Chalcis sispes*, a generally distributed European species, measuring one-third of an inch, is black, with more or less of the legs red. This last insect has been bred from a larva of *Stratiomys*. In *Eulophus pectinicornis*, a minute brassy-black species, a twelfth of an inch long, which is abundant upon oak trees, the antennæ consist of only three joints in the female, while the male has nine joints, three of which (the third to the fifth) bear each a long branch. The species of the genera *Blastophaga* and *Sycophaga*, which are common in the South of Europe, frequent the figs, and assist in the impregnation of the female flowers of those curious trees. Many of the species with elongated ovipositors are parasitic upon the larvæ of Gall Flies. The one figured infests the curious shaggy galls (Bedeguars) of the briar.

CALLIMOME BEDEGUARIS.

FAMILY CYNIPIDÆ, OR GALL FLIES.

In this last family of the Petiolated Hymenoptera, which is referred to the Entomophagous tribe from its structural characters, we find exceedingly few insect-eating species, by far the greater number feeding upon peculiar morbid excrescences of plants, known as galls, the growth of which is caused apparently by the puncture of the parent insect, and the presence of the egg or larva within the tissues. Thus, while they distinctly hold to the Entomophaga by their structure, they seem in their habits to lead towards the plant-eating forms constituting the following tribe.

The Cynipidæ are characterised by their unbent antennæ, which are usually thread-like, and composed of from thirteen to sixteen joints, the number being frequently greater in the males than in the females. The wings show no submarginal cells, except the apical one, and sometimes a very small one just within the stigma, at the apex of the discoidal cell. The abdomen, which is usually short, is strongly compressed, and only the first, or first and second segments, are greatly developed, the remainder being retracted within these, so that only their edges project. These fully-developed segments are much longer at the back than towards the ventral surface, so that the posterior margins of the segments, and that of the abdomen, become very oblique, especially in the female, and thus the ovipositor comes to issue from near the middle of the lower surface of the abdomen. Its arrangement is very peculiar. The last visible segment is produced within the others nearly to the base of the abdomen, where it has articulated to it a small triangular chitinous plate, to which the sheath of the ovipositor is also movably articulated. This sheath, as in the other Entomophaga, consists of two flattened joints on each side of the ovipositor, and the apical joints project from the abdomen, and, passing up along its posterior margin, produce the appearance of a sort of cleft. Within this the ovipositor lies, so that its point is directed upwards. By the action of muscles upon these parts, the ovipositor, which, in repose, is bent more or less in a spiral form, is pushed out from between the side-pieces forming the sheath when it is being employed in egg-laying. It consists, as in the Ichneumons, &c., of a principal superior piece, and two smaller pieces below, the whole arranged so as to form a triangular tube, for the passage of the egg. The latter is remarkable in its structure. It is considerably too large to pass easily through the narrow tube which has to convey it to its destination, but it is prolonged into a narrow tubular part capable of extension, and during deposition a portion of the contents of the egg is forced up into this tubular part, to rejoin the main mass when the process is completed.

The number of species in this family is very considerable, although in this respect it is far inferior to the parasitic families just described. Of the great majority of the species, the females pierce with their ovipositor the tissues of plants and trees, and there deposit their eggs, from which the larvæ are soon hatched. The irritation caused by this intrusion of a foreign body into the tissues would seem to give rise to a morbid state of the part affected, manifested by the production of an excrescence, which varies in size, form, and structure, according to the species of the Gall Fly producing it. The insects are generally confined to one species of plant, and to a particular part of it. The larvæ feed in the interior of the galls, sometimes singly, sometimes several in the same gall, but in the latter case each larva occupies a separate cavity. When full grown, the larvæ either undergo their change to the pupa state within the gall, or eat their way out, and, dropping to the ground, bury themselves under the surface, and there pass through their transformations.

GALL FLY.

INTERIOR OF GALL.

OAK-GALL PRODUCED BY CYNIPS.

The galls produced by different species differ greatly in form and structure. Some of them are round and smooth like fruits, such as the cherry galls of the oak leaves, produced by the puncture of *Cynips quercus-folii;* others show processes, or excrescences, of various kinds, such as may be seen in the well-known ink gall, the gall-nut of commerce, which is formed upon the twigs of a peculiar species growing in the Levant (*Quercus infectoria*), in consequence of the attacks of a rather large species, the *Cynips tinctoria.* This same oak also produces the so-called Dead Sea apples, which have been often celebrated poetically. They are as large and round as a good-sized apple, and each of them contains a single larva of a species described as *Cynips insana.* The most singular of all these galls is perhaps the Bedeguar, which is formed on the stems of wild roses by the puncture of a small species (*Rhodites rosæ*). It is of considerable size, contains numerous larvæ, each in a separate chamber, and has its whole surface covered with compound bristles, like those on the calyx of a moss-rose, so that it closely resembles a ball of moss stuck on the stem or

branches of the rose-bush. The well-known oak-apples, which many people still wear on King Charles's Day, are another form of galls. They are produced on the twigs of oaks by the puncture of *Teras terminalis*. A very curious form of gall, which would generally be taken rather for a parasitic fungus than a gall, is to be found upon oak leaves in every wood. This is a little flat round disc attached to the surface of the leaf by a very small portion of its lower surface. Such galls are produced by two or three species of *Neuroterus*, which may be easily bred from them, if the leaves are collected in the autumn. *Biorhiza aptera*, a wingless species, lives on the roots of the oak.

Singularly enough, we have in this family once more to record cuckoo-like habits, many species of Gall Flies depositing their eggs in the galls produced by other species. The larvæ hatched from these eggs feed upon the substance of the gall, and in the end devour the rightful possessor. These parasites belong to the genus *Synergus*, a common species of which (*S. vulgaris*), black, with the mouth, antennæ, and legs red, breeds in the galls of *Cynips quercus-folii.*

The truly parasitic species form several distinct genera. *Ibalia cultellata*, a large species, measuring half an inch long, black, with a red, knife-shaped abdomen, is parasitic upon the larvæ of wood-boring Beetles, or, according to some writers, upon that of the Tailed Wasp (*Sirex*). The species of *Figites* live upon the larvæ of Flies, and those of *Allotria* upon Aphides. None of them appear to attack insects belonging to their own family, but the true Gall Flies by no means have an immunity from parasites. Many Ichneumonidæ, and especially Chalcididæ, pierce the substance of the galls with their long ovipositors, and place their eggs in the contained larva. Thus *Callimome bedeguaris* (p. 4) haunts the Bedeguar galls, and another species of the same genus even makes its way underground to place its progeny in the root-galls of *Biorhiza.*

A remarkable circumstance connected with the insects of this family is that of a great number of the supposed species, especially those of the genus *Cynips*, only the females are known, the most pertinacious investigation having failed to reveal any males. Hence entomologists, headed by Mr. Siebold, long since came to the conclusion that as the unimpregnated females undoubtedly produce galls, we have here to do with a case of parthenogenesis. Recent researches have shown that in some cases, at any rate, what has been called an "alternation of generations" takes place; that is to say, that the parthenogenetic females are the offspring of male and female insects, so different from them in character as to be placed in different genera.

TRIBE III.—PHYTOPHAGA.

FAMILY UROCERIDÆ, OR TAILED WASPS.

The remainder of the Hymenoptera, forming two families, are, as already stated, confined to a vegetable diet in all stages of their existence. The perfect insects are recognisable at once by their sessile abdomen, and the larvæ are more or less caterpillar-like, possessing six legs, and generally a number of pro-legs, and having a hinder opening to the intestinal canal.

The two families may be distinguished by various characters, but especially by the structure of the ovipositor. In the present family this organ generally projects considerably from the apex of the abdomen, and consists of essentially the same parts as in the preceding families, that is to say, two lateral plates, and a central, more or less serrated style, grooved along its lower surface. The antennæ are filiform, and consist of from eleven to twenty-four joints; the eyes and ocelli are well developed; the abdomen is elongated, usually nearly cylindrical, and composed of nine segments, with the dorsal plate of the first segment divided; and the anterior tibiæ have only a single spine at the apex. The larvæ resemble the grubs of Beetles rather than Caterpillars; they have six thoracic legs, which are often rudimentary, and generally no trace of pro-legs.

These insects present certain rather remarkable peculiarities of structure, such as the division of the dorsal-plate of the first segment of the abdomen already alluded to, the purpose of which is at present unknown; the exceedingly free articulation of the neck-like prosternum with the pronotum, which gives the head great freedom of motion; the movable junction of the meso- and metathorax, which exists in this and the next family, and is a very exceptional character in the class of insects; and the presence of two transverse openings on the metanotum, the so-called "false stigmata," the function of which is unknown.

The family is not an extensive one, and its species occur chiefly in Europe and North America,

in both which regions the typical genus *Sirex* is represented by large species. The best known European species, which is common in some parts of Britain, is the great Tailed Wasp (*Sirex gigas*, figured on p. 353, Vol. V.), a formidable-looking insect, of which the female often measures nearly an inch and a half in length. The general tint is black, with the antennæ, the sides of the head behind, and the tibiæ and tarsi reddish-yellow, and the base and apex of the abdomen yellow. In the male the abdomen is reddish, spotted with black at the sides and apex. The maxillary palpi in this and other species of the genus are rudimentary. The general wasp-like aspect of this insect is sufficiently recognisable in our figure to explain the popular denomination that has been applied to it; indeed, many people mistake it for a Hornet, which they know to be a large Wasp, the long ovipositor of course being regarded as a peculiarly formidable sting. This insect lives in pine and fir-woods, and the female deposits her eggs in the woody parts of the trees, into which she bores to a depth of over half an inch by means of her auger-like ovipositor. The larvæ hatched from these eggs bore deeper into the wood, forming tortuous passages, which gradually become wider as the larvæ increase in size, until they may have a diameter of a sixth of an inch or more. The larvæ themselves are fleshy grubs, with a horny head, and six very short thoracic legs. Of abdominal pro-legs there are no traces. The space left behind by the larva is filled up with a mixture of wood-dust and excrement. The question is not quite settled whether the development of the larva is completed within a single year, but this seems to be the most probable supposition; but as this period of its existence draws towards a close it prepares a somewhat wider chamber for the pupa, and, according to some entomologists (Ratzeburg, &c.), also makes a passage from this chamber to close under the surface of the stem, in order to facilitate the escape of the perfect insect. The latter comes forth in the summer months, and does not appear to enjoy a very long life. Both *Sirex gigas* and a rather smaller species (*S. juvencus*), the latter of a general steel-blue colour, which follow the same mode of life, vary greatly in abundance in different years. Occasionally, when the timber into which the larvæ have bored has been worked up into furniture, or employed in the woodwork of houses, the perfect insects will in due time emerge, sometimes in such numbers as to cause no small alarm to the human inhabitants. In flying, they produce a loud humming, much like that of the Hornet.

The curious little genus *Xiphydria* consists of a few species which have short antennæ, a round head supported upon a singularly long neck, five-jointed maxillary palpi, and an ovipositor shorter than in *Sirex*, although of the same general conformation. The commonest species is *Xiphydria camelus*, a black insect with white spots on the top of the head and along the sides of the abdomen, and with red legs; it is rather more than half an inch in length. This and the other species of the genus bore as larvæ in the wood of various trees (beeches, oaks, poplars, willows, &c). This genus in some respects leads towards the next family, and this is still more the case with another genus (*Cephus*), one species of which (*C. pygmæus*) attacks different kinds of grain-plants, the female boring into the green haulm at one of the uppermost knots, and depositing an egg there. The larva hatched from this egg is almost footless, but it is able to make its way about in the narrow passage of the interior of the haulm, the inner layers of which constitute its food. The presence of this insect may be recognised in the field by the condition of the ears of corn; those of the stalks infested are light, and stand upright, while their healthy neighbours are heavy and bent down. When full grown, about harvest, the larva makes it way to the lowest part of the straw, and there encloses itself in a silken cocoon, in which it passes the winter, only passing to the pupa state a little before the emergence of the imago, which takes place about May.

FAMILY TENTHREDINIDÆ.

A much more extensive family than the preceding is that of the Tenthredinidæ, or Saw Flies, the latter name referring to the peculiar form of their ovipositor. Instead of being a piercing or boring instrument, as in all the preceding families, consisting of an upper channelled piece and two slender pieces closing the channel below, and thus completing the egg-canal, the ovipositor in the Saw Flies is a saw-like blade occupying the apical cleft of the abdomen, and composed of two lateral pieces only. What the precise constitution of this ovipositor may be is rather doubtful, but the two lateral serrated pieces would seem to represent the two inferior bristles of the other ovipositors of Hymenoptera, the unpaired median piece being undeveloped. The antennæ are usually short, frequently more or less

thickened at the apex, sometimes pectinated in the males, and composed in different genera of from three to thirty joints; the ligula is broad, and divided by deep notches into three parts; the maxillary palpi have six joints; the prothorax is produced at the sides to the origin of the fore wings; and the anterior tibiæ have two spurs at the apex.

In their general habits these insects present a considerable uniformity. The females, by means of their saw-like ovipositors, cut slits in the leaves or tender growing shoots of trees and plants; the two plates of the saw are then separated a little, so as to widen the aperture already made, and then an egg passes down to its destination between them. The irritation produced by this process, assisted, according to some entomologists, by a peculiar secretion which accompanies the egg, causes a flow of sap to the wound, and the egg by contact with this quickly becomes considerably enlarged. The larvæ hatched from these eggs are generally very like the caterpillars of Butterflies and Moths in structure and appearance; they all possess three pairs of thoracic legs, and the great majority have, in addition, from six to eight pairs of abdominal pro-legs. These, however, differ from the corresponding organs in the larvæ of the Lepidoptera, by being destitute of the peculiar circlet of generally hooked bristles which the latter possess. The larvæ of the Saw Flies also have only a single simple eye on each side of the head. When full grown the larvæ spin a cocoon, which is sometimes parchment-like in its texture, sometimes lattice-like, and occasionally exhibits a combination of the two characters. These cocoons are either attached to the leaves and twigs of the plants and trees on which the larvæ have lived, or placed underground, but in either case the larva remains unchanged within its cocoon until the time for the emergence of the perfect insect approaches, when it undergoes the change to the pupa state, and from this the imago is speedily produced. The number of known species of the family is estimated at over a thousand, a very considerable proportion of which live in Europe. Many of them are inhabitants of Britain.

The species of the genus *Lyda* have long bristle-shaped antennæ of numerous joints, a broad head, a flat abdomen, and three spines at the apex of the second and third pairs of tibiæ. Two species (*L. pratensis*), a black insect with yellow markings on the head and thorax, and the abdomen margined with rusty red, and *L. campestris*, which is blue-black, with the middle of the abdomen reddish, and the antennæ, scutellum, tibiæ, tarsi, and wings yellow, both about half an inch long, live on pines and firs, the larvæ feeding in company under a sort of web which they spin; another rather smaller species (*Lyda betulæ*), which is reddish-yellow, with the thorax and the base and apex of the abdomen blue-black, feeds on the birch, and is very generally distributed. *Lophyrus pini* is a very common species on coniferous trees. The sexes differ in colour, the male being black with yellow legs, and the female yellow, with the head, three spots on the thorax, and the middle of the abdomen black; the antennæ in the female are serrated, in the male pectinated on both sides. The insect is about a third of an inch long, and, like the species of *Lyda* above mentioned, sometimes does considerable damage. *Nematus ventricosus*, a small reddish-yellow species, about a quarter of an inch long, with the breast and three spots on the back of the thorax blackish, haunts gooseberry and currant bushes, producing two broods in the year, and sometimes almost stripping the bushes of their leaves. *Emphytus grossulariæ* is another enemy of the gooseberry. *Athalia spinarum* is a species of a reddish-yellow colour, with the head and the sides of the posterior part of the thorax black. It measures about a quarter of an inch in length. The larva feeds on the leaves of the turnip and other cruciferous plants, to which it frequently does great mischief. The species of *Hylotoma*, one of which (*H. rosarum*) attacks roses, have only three joints in the antennæ, the last joint being longer than the others; in those of the genus *Cimbex*, which are among the largest in the family, the antennæ have seven or eight joints and terminate in a good-sized club. *Tenthredo æthiops*, a small black species, deposits its eggs upon fruit-trees, showing a preference for cherry-trees. Its larva is black, and often occurs in such abundance as to damage the trees. The larvæ of certain small species mine the leaves of the plants on which they feed; while the irritation caused by the presence of others produces small excrescences or galls within which they live. A common example of this last habit is the little *Nematus saliceti*, the larvæ of which reside in small protuberances of the leaves of several species of willows.

LOPHYRUS PINI, MAGNIFIED.

ORDER NEUROPTERA.

CHAPTER VIII.

THE FLAT-WINGED NEUROPTERA AND THE CADDIS-FLIES.

NEUROPTERA—Characters—Habits—Classification—PLANIPENNIA—MEGALOPTERA — Characters — THE MYRMELEONTIDÆ, OR ANT-LIONS—Habits—Capture of their Prey—THE HEMEROBIDÆ—The Golden-eyed Fly—The Genus *Nemoptera* —THE MANTISPIDÆ—THE SIALIDÆ—The *Sialis lutaria*—The Snake-flies, or Camel-flies—THE PANORPIDÆ—The Scorpion-fly—Habits—Genus *Bittacus*—Genus *Boreus*—TRICHOPTERA—Caddis-flies—Difficulty of Assigning their Proper position—McLachlan's Classification—Characters—Distribution—Metamorphoses—The Phryganeidæ—The Limnophilidæ—The Sericostomidæ—The Leptoceridæ—The Hydropsychidæ—The Rhyacophilidæ—The Hydroptilidæ.

THE order Neuroptera of the older entomologists included all the insects which possess four membranous wings more or less elaborately veined, but not after the Hymenopterous type, the veins running straight through the wing, with a larger or smaller number of branches, and either simply parallel or united by more or less numerous cross veins. The peculiar arrangement of cells seen in the fore wings of the Hymenoptera (see figure on p. 354, Vol. V.) never occurs in these insects. Between the insects thus brought together by the possession of wings more or less similar in character there is, however, a very important difference. Some of them, and the larger number, only pass through an imperfect metamorphosis, being active and voracious in all stages of their existence; while the rest have a complete metamorphosis, the larva being quite different in structure from the perfect insect, and the pupa quiescent.

THE COMMON ANT-LION.

The latter constitute the order Neuroptera of modern authors, and they may be defined as insects with a perfect metamorphosis, a mandibulate mouth, a free prothorax, and four more or less veined membranous wings. It must be confessed, however, that in this definition the character of the metamorphosis is the only one separating them from the other membranous-winged insects which were formerly associated with them, but are now commonly referred to the great order Orthoptera; and further, that from circumstances, especially the remarkable differences presented by the members of both groups among themselves, it is exceedingly difficult to frame a broad definition, applicable to the perfect insects alone, which will serve for the discrimination of the two series.

There is one character, however, which almost universally holds good, and this is derived from the structure of the ligula. Throughout the more highly organised Orthoptera the ligula is, almost without exception, divided or cleft in front, either into two or four lobes, and the indications of division may even continue down into the basal part of the labium, showing very clearly the original construction of the whole labium out of a pair of organs similar to the maxillæ. In the true

Neuroptera, although the ligula is occasionally cleft in front, the general rule is that the parts of the labium are united in the middle line so closely as entirely to conceal the original constitution of the organ of two lateral halves, so that the labium really approaches that of the Beetles more nearly than that of the Orthoptera.

The Neuroptera may be characterised generally as rather soft-skinned insects, with a head of small or moderate size, closely applied to the thorax, and having a pair of well-developed compound eyes, and a pair of usually many-jointed, bristle-shaped, or necklace-like antennæ, which are sometimes clubbed at the end. The ocelli are frequently wanting. The parts of the mouth are variable in their development; their characters will be described under the two principal groups into which we divide the order. The prothorax is always free, sometimes ring-like, sometimes considerably developed; the veins of the wings may be either simple or united by cross-veins; the tarsi are usually of five joints; and the abdomen consists of eight or nine segments. In some cases there are tail-like appendages at the extremity of the abdomen, but these, when present, are not jointed organs such as occur in the Orthoptera.

The Neuroptera have generally a short intestine, usually provided with a sucking stomach, and in many with a globular proventriculus. The Malpighian vessels are long, and from six to eight in number. The females of certain forms are provided with special glands connected with the oviduct, the secretion from which serves to form an envelope for the eggs, or a long stalk upon which they are supported when laid. The larvæ are provided with the usual six thoracic legs, and the abdomen in many species bears peculiar appendages which assist the insect in its movements. Many species, in fact the whole of one of the two great divisions, are aquatic in the larval state. The pupa is sometimes free, sometimes included in a cocoon spun by the larva. In character it resembles the pupæ of the Coleoptera and Hymenoptera, having all the limbs and other appendages enclosed in separate sheaths, and free; but the pupæ of the Neuroptera usually acquire the power of movement just before the emergence of the perfect insect, and this enables them to get into a suitable position for this final change, which is especially important in the case of the aquatic species.

In their habits the Neuroptera present no special peculiarities. They are generally not particularly active in the perfect state; some of them fly in the day time, while others are chiefly on the wing in the evening twilight. Some are carnivorous in their habits, whilst others either feed on the nectar of flowers or abstain altogether from food. The larvæ of one of the two principal groups are carnivorous, those of the other chiefly herbivorous, although animal food does not come amiss to them. The order is but a small one, the number of known species from all parts of the world probably not greatly exceeding 1,500.

The geological distribution of the Neuroptera is very difficult to ascertain, owing to the similarity of the wings of these insects, the chief parts preserved, with those of the Orthopterous Pseudoneuroptera, which, as already stated, were formerly included with them in the same order. It would appear, however, that the order is not of ancient date. The Palæozoic types, which have been described as Neuroptera, seem all to be either Pseudoneuroptera or most nearly allied to that tribe. In the Trias forms which appear to be related to the existing North American genus *Chauliodes* have been met with, and in the Lias and Oolites a few species of different families occur. In Tertiary deposits they are more plentiful, but the number of recorded fossil species is not great.

The Neuroptera as here defined are divided into two principal groups (sub-orders). These are :—

I. Planipennia, having the fore and hind wings similar, usually both in form and structure, the hind wings never broader than the others and folded; the organs of the mouth fully developed and generally distinct, the mandibles being horny biting organs, the maxillæ furnished with two separate lobes, and five or six-jointed palpi, and the labium generally distinct, with three-jointed palpi; the prothorax generally well developed, and the other two segments nearly equal. Larvæ rarely aquatic.

II. Trichoptera, with the wings clothed with hairs or hair-like scales, dissimilar, the hinder ones generally wider than the others and folded, the mandibles reduced to mere membranous rudiments, and the maxillæ and labium united into one mass, the former having palpi of from two to five joints, and the latter either three-jointed palpi or none at all, the prothorax ring-like, and the mesothorax much larger than the metathorax. Larvæ aquatic.

SUB-ORDER I.—PLANIPENNIA.

FAMILY MEGALOPTERA.

This family, which includes the most typical forms of the Planipennia, or Flat-winged Neuroptera, may be at once distinguished by the position of the head, which is set on perpendicularly in front of the thorax, that is, with the mouth directed downwards, but not produced into a sort of beak. The upper surface of the head usually has no ocelli. The parts of the mouth are all separate, and the ligula is not cleft. The abdomen is long and slender.

Although the perfect insects of this family exhibit some divergence in external characters, their larvæ present a close resemblance in structure. They are shorter and flatter in form than the parent insects, and furnished with six well-developed legs. Their food consists of other insects, in the capture of which some of them exhibit remarkable cunning and contrivance, and their instruments for taking nourishment show a very curious modification of the organs of the mouth. The mouth is in fact closed up, the labium, which bears a pair of jointed palpi, being firmly soldered to the under surface of the head; above it is a pair of long, curved, and sharp forceps, formed by the mandibles, which are deeply grooved along their lower surface, and the maxillæ, which are slender, and exactly close the groove in the mandibles from beneath. In this way the two pairs of jaws become converted into a pair of tubular, sickle-shaped forceps, and when the points of these are plunged into the body of another insect, the juices of the latter can readily pass into the two channels, which open at the base directly into the œsophagus. The pupa is enclosed in a cocoon, the material for which is derived from a gland situated in the terminal part of the intestine.

The MYRMELEONTIDÆ, or ANT-LIONS, are among the most interesting forms of this great family. They may be distinguished at once by having their antennæ clubbed at the tip. The larvæ have a rather large head, and the inner edge of the mandibles toothed.

The common ANT-LION (*Myrmeleon europæus*, see figure on p. 9), which is abundant in sandy places in the South of Europe, is a slender and elegant creature, with large finely reticulated wings, not unlike a very delicate form of Dragon-fly. It measures rather more than an inch in length, and is of a blackish colour, with a yellowish head spotted with black, and transparent wings with scattered brownish spots. Its larva, to which the name of Ant-lion properly belongs, is of a stout form and a greyish-yellow colour, covered with warty processes and with hairs. It bears seven simple eyes and a short antenna on each side of the head; its tarsi consist of a single joint, terminated by a pair of strong claws; and it moves in a jerky manner and always backwards. Its food consists of Ants and other small insects, which it captures by a singularly ingenious arrangement, namely, a funnel-shaped pitfall in the sand, at the bottom of which it lies waiting until some unlucky victim, venturing over the margin of the pit, gets upon the treacherous slope of sand, which affords no secure foothold. When the descent of grains of sand reveals the presence of a prey to the Ant-lion patiently waiting below, he throws up a shower of sand which helps the victim in its descent. The labour undergone by the Ant-lion in the construction of his funnel-shaped pitfall is very considerable. He commences by making a circular excavation which marks out the size of the pit, and having completed this, proceeds most laboriously to dig out the space thus circumscribed to the required depth. In doing this he works usually in a spiral direction, always going backwards. The sand is placed by the action of the legs upon the surface of the shovel-like head, and then by a jerk thrown quite beyond the boundary of the pit, and the larva is so active in its operations than when at work it produces a continuous shower of sand. On completing its dwelling it buries itself in the sand at the bottom, frequently, however, allowing its formidable jaws to project a little. The larva is supposed to live for two years. The perfect insect is rather sluggish.

A second species of *Myrmeleon*, with similar habits (*M. formicarius*), is abundant in

Europe; and the larvæ of some other species make no funnel, but simply conceal themselves beneath the sand until their prey comes within reach. There are many exotic species, and some of them, especially in warm climates, reach more than double the dimensions of the European forms, and show a much more vivid colouration. This is the case also with the species of the genus *Palpares*, which have shorter and stouter antennæ than the preceding, and the first four joints of the tarsi very short. *Palpares libelluloides*, which inhabits the South of Europe, is about two inches long and four inches across the wings. It is of a yellowish colour, with black streaks; and the wings are clouded with yellow and adorned with large and small brown spots. The *Ascalaphi* (see figure on p. 13), which much resemble Moths in general form, have the antennæ long and slender, and terminated by very distinct clubs like those of some Butterflies. These insects also are adorned with bright and contrasted colours, which adds to their resemblance to Lepidoptera.

PALPARES LIBELLULOIDES.

The HEMEROBIIDÆ have the antennæ either thread-like or necklace-like, and not clubbed; and their larvæ are slenderer in form and have a smaller head than the Ant-lions. These insects, like the preceding, are of slender and delicate forms, and have very finely reticulated wings, but in general the abdomen is less elongated. Some species are exceedingly abundant and well known in this country, such as the beautiful GOLDEN-EYED FLY (*Chrysopa vulgaris*), which we may take as an example of the group. This is a most delicate green insect, with a body less than half an inch long, which may be seen almost everywhere in warm summer evenings flying slowly about upon four wings having the appearance of green gauze, and consisting of a transparent membrane traversed by a most delicate network of green veins. The prominent hemispherical eyes are of a beautiful golden colour. It emits an exceedingly disagreeable odour. Many other species of this and the nearly allied genus *Hemerobius* occur abundantly in Britain, and all have nearly the same habits. The eggs, which are little round or oval bodies, like small seed-pearls, are deposited by the females in groups upon the leaves of plants and trees, and in *Chrysopa* each egg is supported upon a long and slender stalk, giving it something of the aspect of a small fungus, for which, indeed, these eggs have been mistaken. The stalk is formed by the secretion from a peculiar gland connected with the oviduct. The female, on applying the extremity of her abdomen to the spot on which she purposes to deposit an egg, allows this glutinous material to adhere to the surface, and then raising the end of her abdomen, with the egg still retained within it, draws out the viscid secretion into a slender hair-like thread, upon the upper end of which the egg is borne when it quits the body of its parent. The general characters of the larvæ hatched from these eggs have already been described; they are distinguished from those of the

Ant-lions not only by their form, but by having no denticulations on the inner surface of the jaws. They devote themselves to the destruction of the Aphides which infest various trees and plants in such numbers, and are frequently so injurious to them, and it will easily be understood that a rapidly growing larva of about half an inch long will commit very considerable havoc among such feeble and sluggish creatures as the Plant-lice. In the hop-gardens these larvæ always abound, and one of the species has received the name of *Hemerobius humuli* from this circumstance. The cocoon is attached by the larva to a leaf, and under favourable circumstances the imago soon makes its appearance, so that there are several broods of these insects in the season. These insects may be observed in mild weather until late in the autumn; and they pass the winter in the perfect state in some sheltered locality.

NEMOPTERA COA AND ASCALAPHUS LONGICORNIS.

Several other genera belong to this group, but of these we will notice only the curious forms constituting the genus *Nemoptera*, in which the hind wings, instead of being similar and nearly equal to the fore wings, are very long, forming a sort of strap, of which the extremity is a little dilated, while the fore wings are very much broader than is usual in the family. These insects, which are exceedingly elegant, live in the warmer parts of the Old World, from Southern Europe to Australia. They fly briskly in the hottest sunshine. Their appearance in flight is illustrated in the above figure of the European species (*Nemoptera coa*), which inhabits Turkey and the adjoining parts of Asia and Africa. The transformations are not exactly known, but the larva of *N. coa* is supposed to be a singular little creature described by M. Bertrand Roux under the name of *Necrophilus arenarius*, having an oval body, with an excessively long, slender neck, composed of the prothorax.

The Mantispidæ, including the single genus *Mantispa*, which appear to be most nearly related to the Hemerobiidæ, and, indeed, are referred to that group by some writers, are distinguishable at the first glance by the structure of the fore legs. These are elongated and converted into raptorial organs, resembling those of the Mantidæ, Praying Insects, or Soothsayers, which we shall have to describe under the order Orthoptera, the coxæ being much lengthened, the femora freely articulated at their extremity, somewhat thickened, and spined or toothed beneath, while the tibiæ are attached to the extremity of the femora by a hinge joint, and with the tarsi shut against the lower surface of the thighs, like the blade of a clasp-knife. To add to the resemblance to the Mantidæ the

prothorax is much elongated, and the head is rather broad, with prominent eyes. The species, which are of moderate size and not very numerous, are found in all the warmer parts of the world. A single species (*Mantispa pagana*) is common in Southern Europe.

FAMILY SIALIDÆ.

In this second family of the Planipennia the head is placed nearly horizontally in front of the thorax, so that the opening of the mouth is in its front part instead of beneath. The antennæ are bristle-shaped or thread-like; the ocelli are generally present; the ligula is membranous, cleft in the middle; the fore and hind wings are similar, except that the former have a more dilated anterior margin. The larvæ of all but one exceptional form live in water, and are furnished with branchial filaments on all the abdominal segments; the pupa is not enclosed in a cocoon.

SIALIS LUTARIA.

The common British species (*Sialis lutaria*) is a blackish-brown insect rather more than half an inch long; it is well known as a bait to anglers, and may be found abundantly in the spring and early summer upon walls and palings in the neighbourhood of water, and upon the stems and leaves of grasses and other plants growing in the water or upon its brink. In repose the wings in these insects, as in the Hemerobiidæ, are laid together in the form of a roof on the back of the insect. They are sluggish and inactive and do not readily take to flight. The female deposits a great quantity of brown eggs, attaching them in a compact mass to the stems of rushes and other aquatic plants; the eggs form short cylinders which are attached by one end side by side with great regularity; and the opposite end is suddenly narrowed and terminated by a small slender point. The larva hatched from these eggs is elongated, with a large horny head and powerful mandibles; the three segments of the thorax are also horny, but those of the abdomen are soft, and each furnished with a pair of articulated bristly filaments which serve as gills, and also assist the larva in swimming through the water, which it does with facility. The abdomen is terminated by a long bristly tail. When full grown the larva quits the water and burrows into the soil of the bank, where it forms a little cell and there undergoes its change to the pupa state. The pupa is not enclosed in a cocoon, and shows all the parts of the future insect, each enclosed in its separate sheath. It remains in this condition showing no signs of life, except a brisk twisting of its abdomen if disturbed, until the time comes for the emergence of the perfect insect, which takes place within the chamber.

LARVA AND PUPA OF SIALIS LUTARIA.

This insect and a few of its immediate allies have no ocelli; in the rest of the group three of those organs are present and often of considerable size. The species of *Corydalis* and *Chauliodes* (*Corydalis cornutus* is a well-known North American species) are distributed over the warmer parts of the world; the antennæ are more or less pectinated, especially in the males, and this sex is also further distinguished by the large size of the mandibles and the presence of a pair of forceps-like appendages at the apex of the abdomen. Their larvæ live in the water like those of *Sialis*.

The Snake-flies, or Camel-flies (*Rhaphidiæ*) form a small genus which is now generally referred to this family, but the position of which has given entomologists some trouble. They have a rather large head, with smallish eyes and usually three ocelli, which is attached to a greatly elongated prothorax by a thinnish neck, so that the head has considerable freedom of motion in a vertical direction. The insect usually carries its long prothorax a little elevated, and its head bent down, very much after the fashion of a snake with its head raised. The species are not numerous, and the greater part of those known are inhabitants of Europe, chiefly in the southern parts. Four species live in Britain. The larvæ reside under the bark of trees, where they feed upon minute insects; they have a large prothorax like the perfect insect, and are tolerably active, often wriggling about in a serpentine fashion. The pupa is not enclosed in a cocoon.

FAMILY PANORPIDÆ.

This family is a curious little group, characterised above all things by the perpendicularly placed and greatly elongated head, forming a regular beak, at the end of which the free organs of the mouth are seen, namely, a pair of small toothed mandibles, the lobes of the maxillæ and the maxillary and labial palpi. The maxillæ and labium are more or less united, forming the lower surface of the beak. The insects have longish, filiform antennæ, moderate, oval eyes, usually three ocelli, a ring-shaped prothorax, and generally four precisely similar wings, showing branched longitudinal veins, but very few cross veins. The legs are long, sometimes much elongated. The larvæ, so far as they are known, live in the earth, and are like caterpillars in their general form; they have a horny head, and three pairs of short, thoracic legs; their bodies consist of thirteen segments. The pupa resides in a little chamber underground; in its characters it resembles those of the other Neuroptera, and it has no cocoon.

The species of this family are not numerous, but they are pretty generally distributed over the face of the earth, those of the more typical genera, however, being chiefly inhabitants of the temperate parts of the northern hemisphere. They are predaceous in their habits, feeding upon smaller and weaker insects, which they seize in various ways. Of the typical genus *Panorpa*, the best known species is the Scorpion-fly (*P. communis*), a common British insect, which may be met with almost everywhere about hedge banks. It is rather more than half an inch long, shining black, with the scutellum and legs yellow, the beak, and in the male the last three segments of the abdomen, reddish. The wings are transparent with dark brown spots, which are more or less confluent, and generally form three dark bands. The name of Scorpion-fly is given to this insect in allusion to a peculiarity of the male. In both sexes the segments of the abdomen beyond the sixth become much more slender, and in the females all of them taper gradually towards the extremity, which bears a pair of small three-jointed styles. In the male the seventh and eighth segments are narrow, and generally carried more or less elevated, while the last joint is swelled into a sort of knob, which bears a pair of forceps. When the insect is alive, with this slender tail and its inflated termination raised above the general level of the body, the analogical resemblance to a Scorpion is unmistakable; the terminal swelling is, however, a far more innocent appendage than the Scorpion's sting, and is only a clasping organ which comes into use during the union of the sexes.

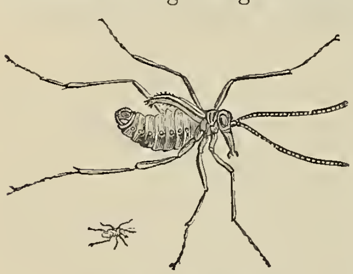
SCORPION-FLY, MALE AND FEMALE.

The common Scorpion-fly is active during the day, and may be found walking about upon the leaves of the herbage in hedge-bottoms and on small bushes, usually in damp situations. Its appearance as it stands upon a leaf is peculiarly brisk and wide awake, and its movements are also lively. It usually pounces upon its prey by short quick flights, and from some observations which have been recorded, it would appear to be a bold marauder, sometimes attacking insects much larger than itself, and boring into them with its long beak. The female, about four days after pairing, deposits, by means of the extensible terminal joints of her abdomen, a mass of little white eggs in a small cavity in damp earth. In a

little more than a week the larvæ are hatched, and they feed upon decomposing vegetable matters which they meet with underground. They have, besides the three pairs of horny thoracic feet, eight pairs of fleshy pro-legs on the following abdominal segments, and from the last segment the larvæ can protrude four short tubes from which a white fluid exudes. The larva is full grown in about a month, and then goes deeper in the earth, where it forms a small chamber, and remains there for a time awaiting its change to the pupa state; and the pupa stays in the same cavity for about a fortnight, and then makes its way to the surface in order to give birth to the imago. The average time required for this development is about nine weeks, and there are thus two broods in the course of the year, the progeny of the second brood surviving the ensuing winter either in the larva or the pupa state.

Another curious genus of this family is *Bittacus*, the species of which have very long bodies and very long legs, and thus closely resemble the common two-winged flies vulgarly known as "Daddy Long-legs" (*Tipula*), in everything but their possession of four wings. The tibiæ of these insects have very long spurs at their apex, and the tarsi have only a single claw; the beak is shorter and the wings longer than in *Panorpa*. The genus includes several species which are chiefly inhabitants of warm climates. *Bittacus tipularius* is the most abundant of the two species found in Europe, and it is confined to the southern parts of the Continent. This insect is about an inch long to the tips of the closed wings. It is of a reddish-yellow-colour, with a great part of the thorax and the tips of the tibiæ and the tarsi brownish. The wings are yellowish without any spots. It is a somewhat sluggish insect, flying slowly and waveringly in the twilight. The *Bittaci* are, nevertheless, as predaceous in their habits as their more active relatives, the Scorpion-flies; but instead of going in pursuit of their prey, they adopt the lazier method of hanging themselves up to a twig by their fore feet, and seizing with their other long legs any unfortunate flying insect that comes within reach. Curiously enough, the pairing of these insects takes place when they are suspended as above described, and, as a general rule, the pair are engaged in devouring some small insect which they hold between them with their disengaged feet. This remarkable habit is not altogether peculiar to the *Bittaci*, the females of several predaceous flies being always engaged in sucking some prey during the time of pairing, the reason being, no doubt in all cases, that if the male ventured to pay any attention to his partner while her mouth was disengaged he would himself fall a victim to his own temerity and her voracity.

Besides these amply winged forms we have to refer to the Panorpidæ some very curious little creatures forming the genus *Boreus*, in which the wings are useless for flight, quite rudimentary in the females, longer and claw-like in the males. These insects have the beak long, the antennæ almost as long as the body, no ocelli, and two claws on the tarsi. The female has a projecting ovipositor. To make up for their want of wings these insects possess a considerable power of leaping; in fact, the common European species was described by one of the older entomologists as a cricket on this account. This common species, which occurs, although not abundantly, in Britain, is called *Boreus hiemalis*, both its names referring to its being peculiarly a northern and winter insect. It does not exceed a sixth of an inch in length, and is of a metallic green colour, with the beak, antennæ, legs, rudimentary wings, and ovipositor, rusty red. From October to March is the season at which this curious little creature is most commonly met with. It is found on the ground among fallen leaves, or upon the snow, and is even met with on the ice of glaciers. The larva lives in moss, and buries itself in dry ground when about to change to the pupa state. Both larva and pupa much resemble those of the Scorpion-fly. Several other species are known, especially in North America, and all have the same habits.


BOREUS HIEMALIS, MALE.

SUB-ORDER II.—TRICHOPTERA.

The members of this group are the insects commonly known as *Caddis Flies*, and we have retained them as belonging to the Neuroptera, although some entomologists are inclined to rank them as a distinct order of insects. This, indeed, was done many years ago by Kirby, and he was

followed in this course by English writers generally (such as Leach, Westwood, and Stephens); and Mr. McLachlan, in his monograph of the European species of the group, also states that his tendency is to separate them from the other Neuroptera. Their relationship to the Saw-flies among the Hymenoptera has been exaggerated; but, on the other hand, their close affinity to the Lepidoptera, through some of the lower forms of that order, is unmistakable.

The systematic study of these insects is attended with very considerable difficulties, owing, to a great extent, to the obscurity and minuteness of the distinguishing marks to which it is necessary to have recourse. In general character, in the nature of the metamorphosis, and in the mode of life of the insects there is such an agreement as would seem to mark them as one family, and by most entomologists they are so treated. To divide them up into subordinate groups (families or sub-families) it is necessary to appeal to very minute distinctive features. Nevertheless, it will be of use to the reader to have a classification of these insects to refer to, and we therefore reproduce here, with some modifications, the table of families given by Mr. McLachlan in his admirable "Monographic Revision and Synopsis of the European Trichoptera," which has already been alluded to:—

DIVISION I.—INÆQUIPALPIA.

Maxillary palpi, differing in the number of joints in the two sexes; five-jointed in the females:—

A. Form of maxillary palpi similar in both sexes; those of the male not very pubescent:—

1. Maxillary palpi of the male four-jointed . . . . . . PHRYGANEIDÆ.
2. Maxillary palpi of the male three-jointed . . . . . . LIMNOPHILIDÆ.

B. Maxillary palpi of males two or three-jointed, very different from those of the females, usually very pubescent . . . . SERICOSTOMIDÆ.

DIVISION II.—ÆQUIPALPIA.

Maxillary palpi, five-jointed, and usually similar in form, in the two sexes:—

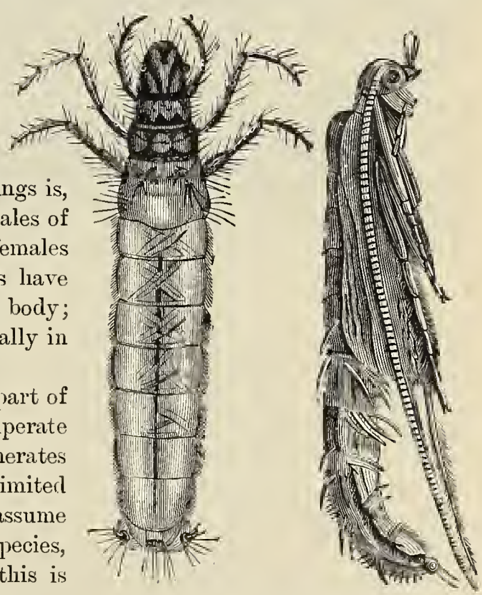
A. Maxillary palpi, strongly hairy, usually ascending, the last joint long but simple; wings pubescent; antennæ long and slender . . . . LEPTOCERIDÆ.

B. Palpi either rudimentary or long, more or less bent down, with the last joint whip-like, composed of numerous minute jointlets; antennæ variable . . . . HYDROPSYCHIDÆ.

C. Palpi bent down, rarely hairy, last joint like the others . . . . . RHYACOPHILIDÆ.

D. Palpi simple in structure, very hairy; antennæ short and stout; insects minute, very pubescent and hairy . . . . HYDROPTILIDÆ.

The Trichoptera are for the most part moth-like insects, having a smallish head, with the mouth downwards, and usually three ocelli at the vertex; the antennæ are bristle-shaped, generally long, and the first joint is thicker than the rest and more or less elongated; the eyes are hemispherical; the wings differ in form, the hinder ones being wider, shorter, and more rounded than the anterior; in repose the wings wrap round the body, and, in consequence, the hind wings are folded. The number of transverse veins in the wings is always very small, and the surface of the wings is, with very few exceptions, clothed with hairs. In the males of a few species the hinder wings are rudimentary, and the females of *Enoicyla* are almost destitute of wings. The legs have large, conical coxæ, meeting in the middle line of the body; and the tibiæ are spurred at the apex, and also generally in the middle.



LARVA AND NYMPH OF SPECIES OF THE GENUS LIMNOPHILUS, ENLARGED.

Species of this group are found in nearly every part of the earth, but they seem to be most abundant in temperate climates. Mr. McLachlan, in the work already cited, enumerates in all 474 species from the European region, which, as limited by him, includes certain parts of Western Asia. If we assume that these constitute about one-half of the known species, we may estimate the total at about 1,000. No doubt this is very far from the whole number of Trichoptera existing on the earth. They are insects which do not greatly attract the

travelling collector, and judging from Dr. Fritz Müller's article on the dwellings of the Trichoptera of the neighbourhood of Santa Catharina, in Southern Brazil, we may fairly assume that when the Caddis-flies of tropical countries have been better studied, the present apparent preponderance of the species of temperate climates will at any rate be considerably diminished. The insects are found about water, generally resting upon the leaves of plants or upon the trunks of trees and palings. Some of them are tolerably active in the day-time, whilst others move about only in the evening and night. The females deposit their eggs upon plants growing in or close to the water, or upon stones similarly situated. The eggs are enclosed together in a gelatinous mass, formed by the secretion from a pair of large glands connected with the oviduct.

THE METAMORPHOSIS OF THE CADDIS FLIES, LIMNOPHILUS FLAVICORNIS, L. LUNATUS, AND L. RHOMBICUS.

We have already noticed the resemblance of the perfect insects to Moths, and the larvæ also present a similarity to the caterpillars of many Lepidoptera. They are elongated, more or less cylindrical, soft-bodied creatures, having only the head, the segments of the thorax, or some of them, and the six thoracic legs horny; and the segments of the abdomen, from the second onward, are usually amply provided with branchial filaments, two or three of which spring from a point on each side of the segments on the dorsal or ventral surface. To protect this soft body the larva makes himself a little habitation, which is composed of the most various materials by different species. Fragments of wood and leaves, short lengths of reeds, and other hollow stems, small stones and grains of sand, little shells, often with their owners still living in them, and sometimes even the cases of other smaller Caddises are made use of; but each species usually employs the same materials, or, at any rate, the same class of materials in the construction of its dwellings. These materials, whatever they may be, are held together by means of silky threads produced by glands which have their opening in the labium of the larva. The cases are often at first tapering; but in most instances the larva prefers a cylindrical dwelling, and after a time removes the slender posterior end and uses the materials, along with others, to add to the length of the case at the wider end. The cases are open at both ends, and in some instances the larva appears to turn round in his

house. Some larvæ have fixed cases, others move freely about by protruding the head and first two thoracic segments from the mouth of the case, when they are able to walk upon the feet attached to those segments. Their hold of the interior of their dwelling is secured in part by the legs of the third pair, which are often much elongated, and in part by certain more or less hook-like appendages to the apex of the abdomen. The long hind legs are mainly instrumental in drawing the larva back within its case, which they can do very rapidly should any danger threaten, the Caddis-worms, as they are commonly called by anglers, being not unwelcome articles of food to fishes and other predaceous aquatic animals. We must add that the larvæ of different species live in all sorts of water, from the most stagnant pond to the mountain torrent, and that their food consists chiefly of aquatic plants, although occasionally they will not disdain animal food.

When full grown, the larva prepares for its change to the pupa state by shortening its case, and closing both apertures of its dwelling with silk and vegetable materials or small stones, but so that the water still has free access to the interior, the closure being sometimes effected by a circular grating of very ingenious construction. The case is also attached and often strengthened at this time. The change to the pupa then takes place within the case, and after a longer or shorter time the pupa breaks out of its dwelling and makes its way out of the water, in order to cast off its last covering, and give birth to the perfect insect.

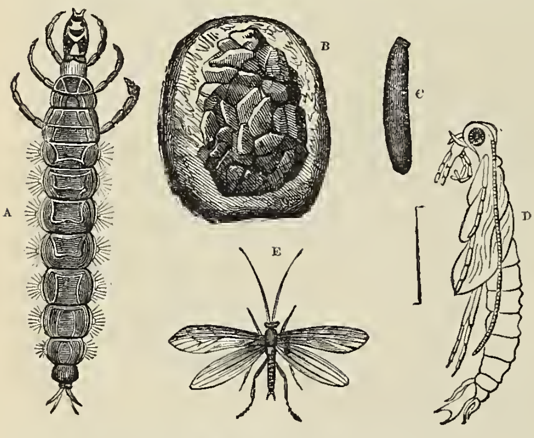
The Phryganeidæ include the largest species of the order, although found only in northern regions. Thus *Neuronia phalænoides*, a north European species, which occurs in Northern Asia, but does not extend its range so far west as Britain, measures nearly an inch long in body, and has an expanse of wing of about two inches and a half. It is a black insect, with white wings, variegated with numerous black spots. One of our largest British species is the *Phryganea grandis*, which measures four-fifths of an inch in length, and over two inches in expanse of wing. It is an abundant insect, of a brown colour, with yellow rings on the antennæ, and the anterior wings ash-coloured, clouded with brown. The larvæ of this group inhabit quiet waters, ponds, lakes, &c. Their cases are cylindrical, and formed of vegetable materials, such as fragments of leaves, fibres, &c., usually arranged in a more or less spiral manner.

The Limnophilidæ are a very extensive group, many species of which occur in Britain. The larvæ live both in standing and running water, and some of them even in torrents. Their cases are very varied in structure. *Limnophilus rhombicus* (see figure on p. 18) forms a case of vegetable fragments, such as detached fibres, portions of grass, and bits of moss, which are arranged transversely, so that the outer surface presents a rough, bristling appearance. *L. flavicornis* (see figure on p. 18) uses a variety of materials in the construction of its case, such as fragments of wood, shells, and small stones, but entire shells, often with the living inhabitants, are the most common. Another species (*L. stigma*) employs small round pieces of the leaves of willows, which are laid one over the other, while *L. lunatus* (see figure on p. 18) makes a case of sand grains mixed with vegetable matter, and then attaches to the outside larger pieces of wood, and even long twigs, which may project beyond both ends of the case. This species lives in standing water. The larva of *L. politus* takes up its abode in a fragment of reed, which it bites to the right length, and then attaches long twigs to it at both ends, and that of *L. vittatus* makes a curved cylindrical tube of fine sand. The larvæ of the genus *Stenophylax* live in running water, and often in mountain torrents. Their cases are generally tubular, formed of fine sand, and temporarily attached to large stones, or the larvæ keep their cases free, and shelter themselves behind stones at the bottom of the water. *Thamastes dipterus*, a Siberian species, is remarkable for having the posterior wings quite rudimentary, and the maxillary palpi three-jointed in both sexes. The species of *Enoicyla* have the females nearly wingless, the wings being represented only by triangular scales. The larvæ live among moss at the roots of trees, and often at a great distance from water. They make a cylindrical case, composed of fine sand-grains, usually more or less mixed with morsels of bark and other vegetable matters. Parthenogenesis is believed by Mr. McLachlan to occur in some species of *Apatania*, of which no males have ever been seen. *Apatania muliebris*, an inhabitant of some parts of the South of England, is one of these.

Of the Sericostomidæ, the larvæ generally inhabit streams, and dwell in a free case, which is usually formed of sand and small stones. In some, such as the species of *Goëra* and *Silo*, the

case is formed as above, of coarse sand-grains and small stones, but in addition to these the larva adds larger angular stones along the sides, which give the case a very broad and depressed appearance. *Brachycentrus nubilus*, a British species, makes a quadrangular case of vegetable materials. The most remarkable cases formed by larvæ of this group are those of the genus *Helicopsyche*, several species of which occur in the South of Europe, and one is recorded from North America, while some analogous forms are described by Dr. Fritz Müller as occurring in Brazil. The cases of the larvæ are composed of sand-grains and small stones imbedded in the silken material forming the actual case; but, unlike any of the cases already described, they are of a spiral form, exactly resembling small snail-shells, and in fact they were at first taken for the shells of small fresh-water mollusca. They appear generally to live in the water, but Professor Von Siebold found them at Lugano, in Italy, under dead leaves in a wet rocky spot.

The case formed by the larvæ of the Leptoceridæ is usually a cylindrical, slightly curved tube, composed of sand-grains, to the surface of which long twigs are sometimes attached. The larvæ live both in standing and running water, but generally avoid strong currents. The case of the larva of *Molanna augustata*, a British species, which usually inhabits standing water, is described by Mr. McLachlan as follows :—" It consists of an inner tube, but the external aspect is very broad and flattened, convex above, with the head-end produced far over the termination of the tube, forming a cover partially protecting the larva when feeding; beneath, the case is slightly convex in the tubular portion, but the sides are dilated in a concave manner. The material employed is fine sand, but to the outside of this, above, are fixed large angular flakes of silex, and, more rarely, vegetable fragments." This larva always lives upon a sandy bottom, where its case is very difficult to detect unless the inmate moves. Two British species of *Setodes* (*S. tineiformis* and *interrupta*) live in cases composed solely of hardened silken secretion, with no sand or other extraneous matters attached to them.



LARVA (A), LARVA-CASE (B), COCOON (C), PUPA (D), AND IMAGO (E), OF RHYACOPHILA VULGARIS.

Of the Hydropsychidæ, the larvæ live both in standing and running water, but more commonly in the latter, and they appear to be to a great extent carnivorous in their habits. Their cases are free, usually consisting of irregular oval masses of small stones, attached to the surface of larger stones at the bottom of the water. Sometimes the larvæ live gregariously under a common roof, composed chiefly of vegetable *débris* fastened together with silk, but then they make separate cases in which to pass the pupa state. The species of the genus *Tinodes*, and some others, make silken galleries upon the surface of submerged stones, &c.

The Rhyacophilidæ, which include many species, especially in the typical genus *Rhyacophila*, agree with the preceding in their general habits, and many of them frequent torrents. The pupa is enclosed in a special brown cocoon within the case.

Finally, the Hydroptilidæ, which include a great number of very minute species, some of them barely an eighth of an inch across the wings, make little cases of silk resembling seeds, to the outer surface of which a few minute sand-grains, portions of diatoms, &c., are attached. These cases have a slit at each end, and the larva can protrude its head at either of them. The larvæ inhabit both standing and running waters.

W. S. DALLAS.

ORDER LEPIDOPTERA (BUTTERFLIES AND MOTHS).

CHAPTER IX.

THE METAMORPHOSES OF THE LEPIDOPTERA.

Characteristics of the Order—EGG STATE—Structure and Development of Eggs—LARVA STATE—Shape and Structure—Stinging Larvæ—Internal Anatomy—Food—Enemies—Growth and Development—METAMORPHOSIS—Pupation of *Vanessa urticæ*—Of other Butterflies—Of Moths which form a Cocoon—PUPA STATE—Structure of Pupa—Development—Emergence of the Imago.—IMAGO, OR PERFECT STATE—Wings—Neuration—Scales—Legs—Head and Body—Internal Anatomy—Food—Senses—Geographical Distribution—Collecting—Killing—Setting—Relaxing—Localities.

THE order Lepidoptera, or Scale-winged Insects,* includes the Butterflies and Moths, of which at least fifty thousand species have already been described. They may readily be distinguished from all other insects by their being provided with four wings, clothed with scales, in the perfect state. Their metamorphosis is complete—that is, they pass successively through the four stages of egg, larva (or caterpillar), pupa (or chrysalis), and perfect insect. These changes we have now to consider.

The parent Butterfly or Moth lays her eggs on the plant or other substance which is best suited for the food of the larvæ when they hatch. Some species lay their eggs singly, while others lay them in a cluster, like the Gold-tail Moth, which covers them with down plucked from her own body, or the Lackey Moth, which glues them in a ring round the small branch of a tree. In any case, they are always so placed as to ensure the safety and comfort of the larvæ.

The eggs are very interesting microscopic objects. They are covered with a hard shell, so that they are not easily injured, and their shapes and colours are very various. Some are globular, others are egg-shaped, or resemble cheeses, barrels, turbans, &c. Some are smooth, but they are more frequently ribbed, fluted, or striated in such a manner as to form exceedingly elegant and complicated patterns. They are most often greenish, but are sometimes brown, blue, red, or yellow, and are not unfrequently spotted or striped.

When the eggs are laid they are perfectly opaque, and the interior is divided into two layers, not always sharply differentiated from each other. The inner portion, however, is more liquid than the other, and in this arise "amœboid cells," or bodies of an irregular star-shape, which appear first at the upper end of the egg, and multiply until they reach the surface, when they become globular in form, and gradually extend all over it. At the same time they multiply downwards, at length becoming conglomerated into a spindle-shaped mass, in the centre of which appears a longitudinal streak.

After this stage is reached, the development of the embryo proceeds rapidly, and when the infant larva is fully formed the egg-shell frequently becomes semi-transparent, so that the occupant may be seen coiled up inside. The duration of the egg-state is sometimes variable, even in the same species; for when two or more broods of an insect appear in the course of one season, the eggs which are laid in the summer hatch in a few days, while those laid by the last autumn brood do not hatch until the following spring. But in such a case the larva is often fully developed in the autumn, and lies dormant in the egg during the winter, ready to burst from its prison as soon as the vegetation of the next season shall be sufficiently advanced to provide it with appropriate food. Sometimes, too, when young larvæ are hatched in autumn, they retire at once to winter quarters, and eat nothing until the following spring.

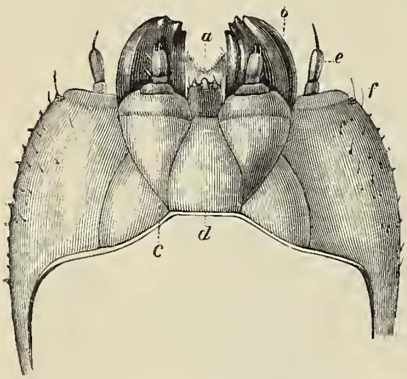
All eggs, however, do not arrive at maturity. Unfertilised eggs do not usually hatch, although parthenogenesis sometimes takes place in the Silkworm and other large Moths, while it seems to be almost the rule among some of the smaller Moths, especially in the genus *Solenobia,* the wingless case-bearing females of which may go on reproducing their kind for generation after generation, like *Aphides,* without the appearance or intervention of any male.

Lepidoptera are very subject to the attacks of parasites in their earlier stages, and many of their eggs are destroyed by small four-winged flies belonging to the order Hymenoptera and the family

* Greek : *lepis,* a scale ; *pteron,* a wing.

Proctotrypidæ. These lay their eggs (one or more, according to the species) in those of Lepidoptera or other insects, and the larvæ which issue from them speedily devour the contents.

If the evolved larva has escaped this danger, it gnaws its way out of its shell, and not unfrequently devours the remainder before tasting other food. In this second stage of its existence the insect is generally of a cylindrical shape, and is composed of thirteen joints, which are called "segments," and are more or less distinctly separated from each other. The head forms the first segment. It is always well marked, and is of a bony consistence, much harder than the rest of the body. The upper part consists of two lobes, separated above by a longitudinal division. The upper part of the face is called the clypeus, or shield, which varies in shape in different species, and below this is the upper lip, or labrum. Six very minute ocelli, stemmata, or simple eyes, as they are variously called, are arranged in a semicircle on each side the mouth.* Below the labrum are the mandibles, and it is worthy of notice that although Lepidoptera are haustellate, or sucking insects in the perfect state, they are always mandibulate in the larva. The antennæ are small, pointed, movable projections, placed at the base of the mandibles. They are generally four-jointed. Beneath the mandibles are a pair of lower jaws (maxillæ), which are soft and membranous, and fitted for holding rather than biting their food. They are furnished with two small four-jointed organs, called maxillary palpi, and behind these parts is situated the membranous lower lip, or labium, below and on the inside of which are two small two-jointed organs, called labial palpi. At the extremity of the labium is situated a conical jointed projection, called the spinneret, from whence issue the threads used by the larva in the construction of its cocoon, and in the case of some gregarious species, its nest.



MOUTH OF LARVA OF THE PRIVET HAWK MOTH.

a, Upper Lip; *b*, Mandibles; *c*, Jaws; *d*, Lower Lip; *e*, Antennæ; *f*, Eyes.

The twelve segments forming the body of the larva are covered with a soft flexible skin, which may be either smooth, granulated, hairy, or spiny. The three segments behind the head which correspond to the thorax of the perfect insect are each furnished with a pair of true legs, consisting of three cylindrical joints, covered by a horny skin, and terminated by a claw. In some species, as in the larva of the Lobster Moth (*Stauropus fagi*), these legs are of extraordinary length. If one or more of these legs should be amputated, the corresponding leg of the imago will also be more or less defective. There is often a horny plate on the back of the second segment behind the head, which is called the scutellum, and there is a triangular flap on the last segment, above the anus, which is often horny, and is called the abdominal fold. Each segment, except the first, third, fourth, and last, is provided with a small opening on each side, above the feet, which is surrounded by a horny margin. These openings are the spiracles, through which the insect breathes, and they are generally placed on round coloured spots, called stigmata. Those on the second and twelfth segments are the largest.

Besides the six true legs, the larvæ of Lepidoptera are furnished with from one to four pairs of fleshy "pro-legs" on segments 7—10, and an additional pair, called "claspers," which terminate the last segment. No European larva has more than sixteen legs, but the larvæ of some American *Bombyces* are said to have twenty, segments 6—11 inclusive being furnished with pro-legs. On the other hand, the larvæ of the *Geometridæ* have only ten legs, those on segments 7—9 being obsolete. Those of the *Nepticulidæ* have nine pairs of ill-developed pro-legs, but no true legs, and those of the *Limacodidæ* are entirely footless.

The pro-legs consist of two fleshy joints, and are adapted for climbing. In the case of larvæ which live exposed they are rough at the extremity, and furnished with a circle of small hooks directed inwards; but in those which live inside the stems of plants they are smooth, and provided with hooks directed outwards. In many *Notodontidæ* the claspers are replaced by two long slender appendages, which sometimes enclose retractile filaments, as in the larva of the Puss Moth (*Cerura vinula*); and in the *Drepanulidæ* the last segment terminates in a double point.

* Six is the usual number on each side in the larvæ of *Lepidoptera*, but it is not invariable.

Many larvæ are smooth and naked, or thinly covered with hair. Others are covered with a close pile, and some, like the Tiger Moths (*Arctiidæ*), with thick, shaggy hair. Some are tufted or spiny, while others are furnished with humps, warts, or tubercles, varying in size and position according to the species, and the tufts of hair are often placed upon such prominences. The retractile appendages at the extremity of the body of the larva of *Cerura vinula*, already mentioned, as well as the retractile fork found on the back of the neck of the larvæ of all the true *Papilionidæ*, are believed to be designed to drive away Ichneumon Flies or other enemies. Birds will seldom eat brightly-coloured or hairy larvæ, but they greedily devour naked larvæ of a green or brown colour, which rely rather on means of concealment than on external defences against their enemies. But some larvæ are furnished with very formidable weapons. The nests of the different species of Processionary Caterpillars (*Cnethocampa*) are dangerous to approach, on account of the fine barbed hairs of the caterpillars, and a highly-irritating dust, which float about in the surrounding air. Many foreign larvæ, chiefly belonging to the *Bombyces*, are actually provided with clusters of stings, consisting sometimes of fleshy branching spines, some of which are thick and truncated at the extremity, and set with fine, sharp, stinging bristles, while others are simply pointed. Others are provided with tufts of hair, some bristle-like and others finely pointed; while the broad footless larvæ of the *Limacodidæ* are provided with spines filled with a coloured liquid, and terminating in a knob set with short sharp bristles. These fascicles of stings are darted forth by the larva whenever it is alarmed, and cause a long-continued burning pain.

The basis of the nervous system in insects consists of two double longitudinal cords running along the under surface of the body (see Vol. V., pp. 290, 291). Each of these is itself double, and the upper one is very indistinctly marked in Lepidoptera. It is in the lower one only that ganglia, or knots of nervous matter, are placed. In the larvæ of Lepidoptera there are thirteen pairs of ganglia. The anterior pair, situated above the œsophagus, or gullet, represents the brain; and the first of those situated below it represents the *medulla oblongata*. Leaving this, which Newport calls the first sub-œsophageal ganglion, the cords which correspond to the *crura* run on each side of the œsophagus into the second segment, where they form the second sub-œsophageal ganglion. Beyond this and the following ganglion, which is placed at the back of the third segment, the cords diverge to include the insertion of the first and second series of diagonal muscles; the two following ganglia, situated towards the extremity of the fourth and fifth segments respectively, completing the thoracic system. The cords are continued beyond, forming a double ganglion in each segment up to the eleventh, where the large terminal ganglion, formed by the fusion of those belonging to the eleventh and twelfth segments, is situated. In some larvæ these ganglia are distinctly separated, in which case fourteen pairs are present instead of thirteen. Great changes, however, take place in the nervous system during the pupa state, when the four thoracic ganglia fuse into two large ones, which distribute nerves to the legs and the muscles of the wings, while the two following ganglia either disappear entirely or amalgamate with the others.

The digestive system is very simple in the larvæ of Lepidoptera, in which it commences by a distinct œsophagus, which terminates by a valvular orifice in the third segment in a long muscular stomach, terminating in the pylorus and ilium. The Malpighian vessels empty themselves into the ilium, which is followed by a lobed cæcum, a very large colon, and a short rectum. Of the muscles of larvæ, suffice it to say that they are very numerous and complicated, especially in the head, in which the large muscles which move the mandibles occupy the greater part of the back and sides.

The respiratory and circulatory systems differ little from those of other insects, but a few aquatic larvæ (*Paraponyx*, &c.), are provided with branchiæ.

The food of caterpillars is very various, and there is scarcely any animal or vegetable substance which some of them will not attack. But though many species will eat a variety of plants, others are only able to subsist on one, or at most two or three; and all are more or less restricted in their food, and must die if they cannot obtain it. The great majority live exposed, and feed on the leaves of plants, but some prefer the flowers or seeds. Others are internal feeders, and live actually within the stems of plants, or even in the branches, trunks, or roots of trees, boring galleries through the solid wood, and often destroying the trees. Some caterpillars prefer withered leaves to fresh, and others, chiefly among the smaller Moths, feed on butter, leather, horn, dried fruits, corn, hair, cloth,

and other artificial or dried produce. Many of the caterpillars of the smaller Moths burrow in the leaves of trees, forming galleries or blotches, easily perceptible from their paler colouring. This habit is not confined to the small Moths. Some larger species, such as the Green Foresters (*Ino statices*, &c.), are miners when young, and the larvæ of many two-winged flies mine in leaves in the same manner. Some few caterpillars produce galls, and others inhabit cases resembling those formed by the larvæ of the Caddis-flies, which they construct out of bits of twig, leaves, or grass. The caterpillars of the Clothes Moths actually clothe themselves in a tight-fitting jacket, open at both ends, which they enlarge when necessary.

During this stage of its existence the insect has nothing to do but eat, and it grows very rapidly. When its skin becomes too small it is cast off, even the skin of the head and the lining of some of the internal organs being thrown off with the rest. Most caterpillars moult four or five times, although some moult only twice, and others as many as six or seven times. So serious an operation is necessarily attended by temporary weakness and discomfort, but the caterpillar soon recovers itself, and begins to eat again as fast as ever, frequently devouring its own cast-off exuviæ, before it returns to its ordinary food. The colour and markings, and even the very structure of the caterpillar, are frequently changed after moulting.

Caterpillars are exposed to many enemies. The most formidable are the Ichneumon Flies, which pierce their skins, and lay an egg in each wound. These eggs soon hatch into small larvæ, which live inside the caterpillar, feeding on the fatty portions of its body, but avoiding all the vital parts. When they have arrived at maturity, they emerge from the skin of the caterpillar and form their cocoons round its dead body. Sometimes the caterpillar lives to assume the pupa state, and the Ichneumon Flies come to maturity within the pupa skin. In their perfect state they are flies, with four transparent wings and a slender body, terminated by a long ovipositor. Birds, wasps, and insectivorous animals in general destroy many caterpillars, notwithstauding the various means of defence or concealment possessed by the latter, which are sometimes truly extraordinary.

One of the most remarkable cases of protective resemblance on record was observed by Mr. Bates on the Amazons. A large caterpillar stretched its head out of a bush, and startled him by its resemblance to a small venomous Snake. He did not succeed in rearing it, but it was perhaps the larva of one of the *Sphingidæ*, for these are large, smooth, and often adorned with very bright colours, such as stripes, bands, and eye like spots.

As the larva approaches maturity it becomes possible to trace the outline of the future Butterfly or Moth beneath the skin, and traces of the wings appear just before the larva is ready to assume the pupa state. The silk-glands also become greatly enlarged in most larvæ when the time approaches for their metamorphosis. They then consist of two long tubes, opening into the spinneret, and closed at the opposite end. They are sometimes much twisted and convoluted, and extend towards the hinder end of the body, partly above and partly below the intestines. The number of convolutions depends upon the length and size of the glands, and in many Butterflies and Moths, which spin only slight cocoons or none at all, the glands are even shorter than the body of the larva, and are only curved twice. These glands are generally of a shining white colour, and can easily be distinguished from the dusky anastomosing tracheal vessels which lie above them. These organs have fulfilled their functions when the insect has assumed the pupa state, and dwindle away so rapidly that after a few days they are reduced to a mere thread.

When the caterpillar is full grown, and is ready to assume the pupa state, it ceases to eat, and its colours generally fade. Sometimes it remains motionless for several hours or days before it commences the difficult and arduous task of pupation, which is effected in various ways.

The small Tortoiseshell Butterfly (*Vanessa urticæ*) may be taken as typical of those Lepidoptera in which the pupa is suspended freely by the tail. When the larva is about to undergo its metamorphosis, it selects a position which it deems suitable, and commences by spinning a little button of silk, strong enough to support the weight of its body. Having completed this work, the larva thrusts its claspers into the middle of the silk button, which projects a little, and swings itself head downwards from this support. The most difficult part of the whole process has now to be accomplished—the extrication of the pupa from the old larva-skin while the latter is thus suspended in mid-air. The larva contracts its body several times until the skin cracks along the back, and the pupa gradually

works itself through the rent by alternately dilating and contracting the rings of its body, and working the larva skin backwards towards the tail. How the tail of the apparently helpless pupa could be withdrawn from the old skin, and fixed in the silk button without the pupa itself falling, long remained unexplained, and it was always supposed that the pupa seized the old larva skin between two of the segments of its body, as with a pair of pincers, and thus worked itself upwards. But according to recent observations of Dr. Osborne this is not so, but the pupa remains connected with the old larva skin by "a membrane extending from the lining of the latter to the anterior horns of the two lateral ridges bounding the anal area of the chrysalis." Some writers regard this membrane as formed of the lining of the tracheæ, which, as well as that of the intestinal canal, is thrown off with the cast skin of the larva. Nor is the membrane the only support of the pupa, for the interior of the larva skin and the surface of the pupa are damp, if not actually wet, at this stage, and the pupa is, therefore, in part at least, upheld by capillary attraction. The chrysalis then stretches up its tail towards the button of silk, and by a series of violent efforts succeeds in reaching it, and in fixing itself by the small hooks with which its tail is provided. It then whirls itself round several times, first in one direction and then in the other, in order to secure its hold, and to fix the hooks as firmly as possible. During this process the connection between the pupa and the cast-off skin of the larva is almost always severed, and the latter falls to the ground.

The pupation of the larvæ of those Butterflies in which the pupa is attached to a stem, horizontally or vertically, by the tail and by a girth of silk round the body, is effected in a very similar manner. Some larvæ, like those of the *Pierinæ*, are sufficiently flexible to attach a thread on one side of their body, and then carry it over, and fasten it on the other side, repeating the operation as often as necessary; but in the case of the *Lycænidæ* the girth is spun first, and the larva slips its head under afterwards. The *Papilioninæ*, on the other hand, spin their girth, holding the separate threads in their claws until the girth is strong enough, when they slip them over their heads. This arrangement is necessary on account of the great risk of entangling the numerous threads of which the girth is composed.

The larvæ of many Moths construct a hollow ball of silk, called a cocoon, in which to pass the pupa state, and it is from the cocoon of the Silkworm and other Moths that the silk of commerce is derived. Some cocoons, like that of the Silkworm are entirely closed, while others, like that of the Emperor Moth, are partially open at one end, being constructed somewhat after the manner of a weir, so that while they form no impediment to the egress of the enclosed Moth, an enemy cannot force its way in from the outside. The larvæ of many *Sphinges*, &c., construct a cell in the ground, lined with agglutinated earth and silk, and those of the Goat Moth and other internal feeders, form their cocoons in the solid wood of trees, forming a tunnel leading up to, but not breaking through, a partition opening upon the outer air. Some cocoons, like those of various *Notodontidæ*, are attached to the bark of trees, which they closely resemble, and are as hard as wood. Many larvæ which spin cocoons construct them in the autumn, and lie dormant till the following spring, without assuming the pupa state till then.

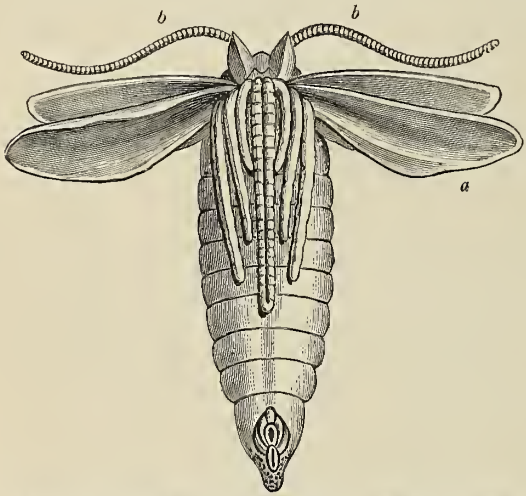
Cocoons are not always made of silk alone. It has already been mentioned that cells made underground are partially formed of agglutinated earth. Hairy caterpillars often weave their hairs into their cocoons, and others employ fragments of leaves, moss, lichen, or comminuted wood. Many larvæ, however, scarcely construct any cocoon, forming their pupæ between leaves or even on the surface of the ground, often without any preparation. Many of the large foreign *Saturniidæ* make their cocoons within a leaf, which they connect with the branch by a strong silken band several inches long, running along the leaf-stalk, so that even if the stalk becomes detached from the branch, the leaf cannot possibly fall to the ground.

It is believed that the object of cocoons is not warmth, but protection; for the temperature within does not exceed that of the surrounding earth or air. Protection, however, is not their only use; for the efforts which the insect makes to escape, and the pressure which the cocoon exerts upon it, are so essential to its development, that pupæ prematurely removed from their cocoons often produce only crippled specimens.

The pupa is generally of a brown colour, but those of Butterflies, which are exposed to the sun and air, are sometimes green, yellow, or metallic. The rudiments of the perfect insect, which can

only be detected in the larva state by a careful and difficult examination, are now easily to be discerned on the outside of the horny envelope of the pupa. But the pupa has no other limbs, and is usually incapable of any function of life, except breathing, or of any motion, except a slight wriggling of the segments of the abdomen. But there are exceptions; some pupæ are able to move about in their cocoons, and those formed in the trunks of trees are provided with small hooks by which they can work themselves along their galleries, and push the head of the pupa through the partition, so that when the Moth emerges it finds itself completely at liberty. The pupa of a Cuban Moth (*Conchylodes diphtheralis*) lies on the ground without any protection, but possesses the power of leaping actively about.

A pupa consists of the thorax, which is the thicker portion, and of the abdomen, which consists of nine movable segments jointed together. The seams in the thorax more or less distinctly indicate the parts of the future Butterfly. The head is visible as a slight swelling in front. It is pressed downwards, and the eyes are visible on each side. Behind and above this is the thorax; and the lower joints of the two first pairs of legs are placed on the under side in front, on the sides of the head. The antennæ pass round the eyes, and run backwards outside the middle pair of legs. The wing cases, which vary in length in different species, lie on the sides of the pupa. In the large *Sphinges*, the proboscis is often furnished with a separate sheath, sometimes convoluted, lying in front of the breast.



CHRYSALIS MAGNIFIED AND PARTIALLY OPENED TO SHOW RUDIMENTARY WINGS (*a*), ANTENNÆ (*b*), AND OTHER ORGANS.

The position of the spiracles is the same in the pupa as in the larva; but not only are the external organs of the future imago developed during the pupa state, but the digestive and nervous systems are profoundly modified, assuming the form which they present in the perfect insect. During the first stages the pupa appears to be filled with a milky fluid, in which the rudiments of the future insect can scarcely be distinguished; but these rapidly acquire consistency, an evaporation, or rather transpiration, taking place constantly, by which the weight of the pupa is eventually much reduced.

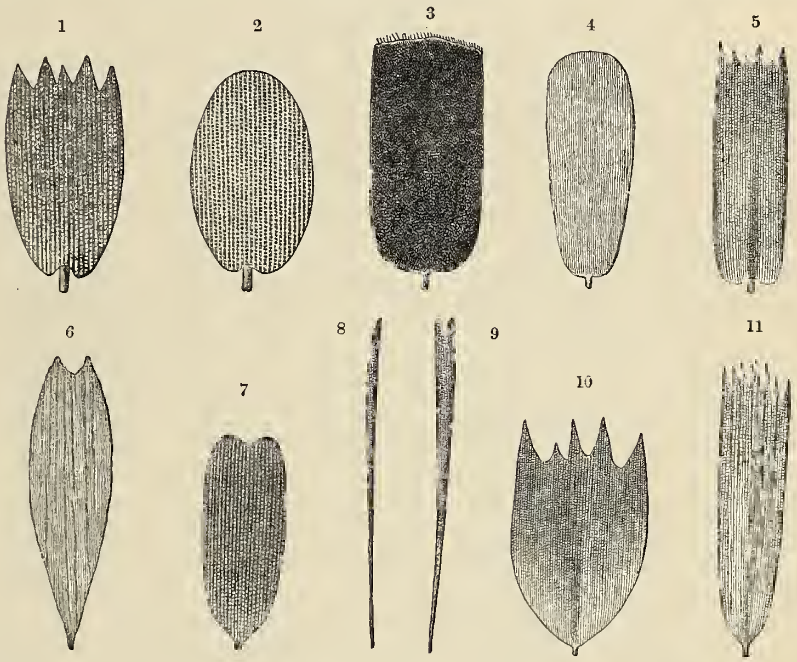
The duration of the pupa state is very different in some insects; but except in the case of summer broods of double-brooded insects, when it frequently lasts only a few days, it extends over several months, for the insect usually passes the winter in this condition. In some cases, especially in the Small Eggar (*Eriogaster lanestris*), the pupæ do not all disclose the perfect insect the same season; but the insects of the same brood appear a few at a time each year, up to fourteen or fifteen years afterwards. The reason for this is obvious in the case of the Small Eggar, for the Moth appears during the inclement month of February, and if all the pupæ belonging to the same brood disclosed the Moth during a single season, the species would be liable to extinction in the event of unusually severe weather.

When the Butterfly or Moth has arrived at maturity, the pupa cracks along the seams, and the perfect insect works itself out, discharging a few drops of fluid at the same time. In some insects this is of a reddish colour; and when the insects were unusually numerous the red spots used occasionally, in superstitious ages, to give rise to the idea that a shower of blood had fallen. In the case of insects enclosed in a cocoon this fluid serves to moisten the silk, or to exert a chemical action upon it (for it is acid, at least in some cases), in order to facilitate the escape of the Moth. Some of the larger *Bombyces* are actually provided with a strong spine under the wings, which helps them to force their way out of the cocoon. As the cocoon is useless for mercantile purposes after the emergence of the Moth, silk-growers always kill the insect before unwinding the silk, by throwing it into boiling water, which likewise renders the silk itself more manageable.

When the perfect insect has quitted the cocoon it is limp and weak. Its abdomen is thick and heavy, and its wings are in a rudimentary condition, but it crawls to a position where it can allow them to hang down, when they can almost be seen to grow, so rapidly do they enlarge to their full size and beauty, in consequence of a fluid being driven through the nervures, which subsequently serve the purpose of air-tubes. The insect then flies away to seek its mate.

In the perfect state, a Butterfly or Moth has four wings covered with scales. In some groups of Moths, however, the males only have developed wings, those of the females being rudimentary, and in almost all species the females are less active than the males. The interlacing nervures, or air-tubes, by which the wings are traversed, form an important aid to the classification of groups. In the centre of each wing we generally find an open space, called the discoidal cell. This is bounded in front by the sub-costal nervure, and behind by the median nervure. Between the costa, or front of the wing, and the sub-costal nervure runs another nervure, called the costal nervure; and between the median nervure and the inner margin (that part of the wing nearest to the body when the wings are laid back) runs another nervure, called the sub-median nervure. These run into the costa or to the lower part of the hind margin without forking; but the sub-costal and median nervures both throw off several branches—or nervules, as they are called—to the costa or to the hind margin, which is the side of the wing farthest from the body. Generally the nervures completely surround the discoidal cell, but in some cases there is an open space at its extremity; and then the discoidal cell is said to be open. But the neuration of the wings is much more complicated in some Moths, the discoidal cell being divided longitudinally, or else small cells may be formed beyond it by the junction or crossing of nervures. When most complicated, the neuration resembles that of the Caddis-flies (*Trichoptera*). But the colours and patterns of the wings are so various that the study of structural characters is less necessary than in other groups of insects.

The muscles which move the wings of Lepidoptera differ little from those of other insects. There are two sets which depress the wings: firstly, a double dorsal muscle, running longitudinally upwards in the meso-thorax; and, secondly, the dorso-ventral muscles of the meso- and meta-thorax, which are attached to the articulations of the wings above, and to the inside of the thorax beneath. Between these lie the muscles, which raise the wings, and which run from the inner side of the back of the thorax to the legs. During flight, the thorax expands and contracts rapidly and constantly.

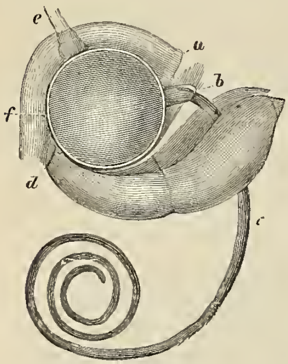


SCALES OF DIFFERENT GENERA OF LEPIDOPTERA.

1, 2, Papilio machaon: 3, 4, Morpho menelaus; 5, Cyclopides aracynthus; 6, Sphecia apiformis; 7, Zygæna filipendulæ; 8, 9, 10, Sphinx ligustri; 11, Pterophorus pentadactylus.

The scales which cover the wings resemble a fine dust, which easily rubs off on the fingers; but if the wing is placed under a microscope, it is found to be covered with a great number of elegantly formed scales of various shapes, some of which are represented on the adjoining woodcut. These are laid over each other, like the tiles on a roof, and are attached to the wing by a small stalk, which, in

some *Morphinæ*, &c., seems to be fixed on the principle of a ball and socket joint. The scales consist of a double membrane, finely striated. Between the striæ, and parallel with them, are arranged pigment cells; but this is not the sole cause of their beautiful colours, for the edges of the scales frequently refract the light, and thus produce the most brilliant metallic lustre. If the scales are rubbed off a colourless membrane remains, with branching nervures running through it. In this state it does not greatly differ from the transparent wings of other insects, except for the sockets from which the scales have been removed.



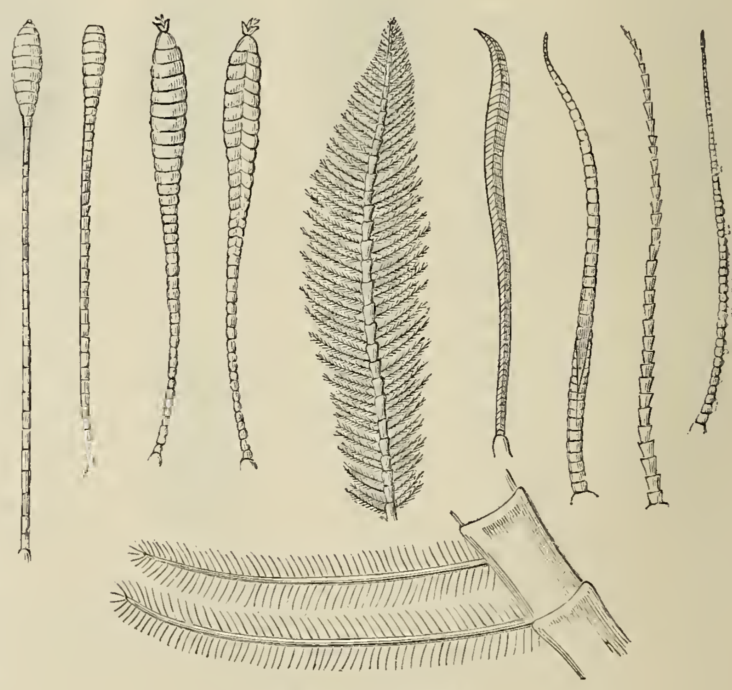
MOUTH OF THE PRIVET HAWK MOTH. (*Magnified.*)

a, Upper Lip: *b*, Mandibles; *c*, Proboscis; *d*, Under Lip; *e*, Antennæ; *f*, Eyes.

Butterflies and Moths have six legs in the perfect state, but in some families of Butterflies the front legs are rudimentary, and in the males of a few Moths the hind legs are shorter than the others.* The tibiæ are not unfrequently furnished with spines in the middle or at the extremity. The tarsi are usually five-jointed, and generally terminate in a pair of claws.

Having noticed the legs and wings, it now becomes necessary to describe the structure of the head and body, before proceeding to notice the internal anatomy. As in all other insects, a fully-developed Moth or Butterfly is composed of thirteen divisions, or segments, the first of which forms the head, segments 2—4 form the thorax, and the remainder form the abdomen. The distinction between the thorax and abdomen is always well marked in the perfect insect, although it is not sharply indicated in the larva.

The head is rounded, and generally rather broader than long. There are two large eyes on each side, formed of a great number of facets, and therefore called compound eyes. Their surface is covered with short hairs in some species, and is naked in others. In addition to these, there are sometimes two small simple eyes (often called stemmata, or ocelli) situated on the vertex or top of the head; but these are not present in many groups of Lepidoptera. The forehead is sometimes provided with a small horn or crest. The antennæ are placed in two small hollows near the eyes, and appear to be organs of touch, hearing, and smell. They are composed of a great number of joints, and in Butterflies they are long and straight, and are thickened into a club at the extremity. In Moths the antennæ are sometimes simply filiform or thread-like, but are more frequently provided with appendages, varying in shape and size. The antennæ are called dentated, or toothed;



ANTENNÆ OF LEPIDOPTERA.

serrated, or saw-like; pectinated, or comb-like; and plumose, or feathery, according to the various appearances assumed by these appendages. The sexes often differ in the development of the antennæ,

* The aborted hind legs of the male of *Hepialus* are said to be used as brushes to scatter round him the odour contained in two pouches with which his abdomen is provided.

and in this case those of the male are always more developed than those of the female. An hermaphrodite of such a species presents a very remarkable appearance when the antenna on one side is pectinated, and that on the other is simple. The antennæ are often clothed with hair or scales, and the basal joint is larger and thicker than the others, except in the Butterflies and *Sphinges*. In some genera of *Tineina* it is expanded into a scale, which partially covers the eye when at rest, and is called the eye-cap.

The parts of the mouth which are best developed in Coleoptera and Hymenoptera are very slightly developed in Lepidoptera, and are almost rudimentary. The only organs which demand attention are the large and overhanging clypeus, the proboscis, and the labial and maxillary palpi. The upper part of the mouth is formed by the small labrum, which is nearly concealed by the overhanging clypeus, and the rudimentary mandibles. Below these is the proboscis, or tongue, which is generally horny. It forms a spiral tube when not in use, but can be stretched out and plunged into the corolla of a flower when the insect desires to feed. It is made of two separate pieces throughout its entire length, so that it can be separated and cleaned if there is any danger of its becoming clogged. In many *Bombyces* the proboscis is nearly obsolete, whereas in the *Sphingidæ* it is often several times as long as the body, and is sometimes liable to become fixed in flowers and broken. The proboscis corresponds to the maxillæ of other insects. At the base of the proboscis are placed the maxillary palpi, which vary in shape and size, and are usually composed of three joints, the last being generally pointed. The lower portion of the mouth is formed by the small triangular labium, on which the labial palpi are placed, which consist of from one to three joints, and are rudimentary in most of the larger Lepidoptera.

The structure of the thorax differs little from what we find in other insects. The prothorax is very narrow above, but is broader below, where the first pair of legs are attached to it. The mesothorax is very large, and is divided longitudinally above. It bears the first pair of wings and the second pair of legs. The former are attached beneath small thin plates called scapulæ. The metathorax is short, and generally consists of five small plates above. The last pair of wings and legs are attached at the sides and on the lower surface respectively.

The abdomen consists of nine movable segments, the hinder margin of each covering the base of the next. The last segment contains the anus and the sexual organs. The male organ is enclosed by two folds, and the female is sometimes provided with an ovipositor. Scent-fans, or scent-pouches, are sometimes placed at the base or extremity of the abdomen in the males.

The whole body is more or less densely clothed with hair or scales, which sometimes form conspicuous crests on the thorax and abdomen.

The nervous system of the larva becomes much modified in the perfect insect. All Lepidoptera have two cephalic ganglia, and the supra-œsophageal ganglion is furnished with convolutions. In most cases there are two distinct thoracic ganglionic masses, the first simple, and the second composite. Sometimes these are close together, and at other times they are more or less widely apart. There are always four abdominal ganglia, the only known exception being in the case of *Hepialus humuli*, which has five.

The digestive system is also modified in the perfect insect. The intestine is much longer than in the larva, and the long and narrow œsophagus is dilated into a large crop in the thoracic segments, which is generally filled with air. The stomach is short, oval, and very muscular, and the ilium is long and narrow, and forms several convolutions, and is covered by the Malpighian vessels throughout its whole length. The colon is large, and is often dilated into a cæcum in front. The salivary glands are simple elongated tubes, and correspond to the silk glands of the larva.

The food of Butterflies and Moths in the perfect state consists of the honey of flowers, honeydew, the exuding sap of trees, over-ripe fruit, &c. The great Death's Head Hawk Moth (*Acherontia Atropos*) will sometimes enter beehives, to feast upon the honey. Nor is this the only enemy which Bees have to fear among Moths; for there are several species of small Moths, the caterpillars of which feed on wax in bee-hives, and often commit great havoc. Many Butterflies are attracted by putrid substances, and others are fond of assembling, sometimes in great numbers, to suck up the moisture from the damp ground.

The senses of Lepidoptera are very acute. They are not unfrequently attracted by artificial or

painted flowers, evidently mistaking them for real. A large number are provided with organs fitted for producing a sound, though it is inaudible to our ears in most cases, although the Death's Head Hawk Moth, and several allied species, are capable of uttering a very audible squeak. The males of those Moths which have highly-developed pectinated antennæ will gather round a box which contains a virgin female, and it is believed that they can be thus attracted from a distance of a mile or more. The males of various species are also provided with tufts of hair, which emit a distinct odour. These are sometimes placed between the wings, and sometimes on the antennæ, legs, or abdomen. This is specially noticeable in our British Privet and Convolvulus Hawk Moths (*Sphinx ligustri* and *Convolvuli*), the males of which emit a musky scent. In these cases the odour is believed to be attractive rather than protective, but some of the insects which are refused by birds appear really to owe their immunity to their disagreeable smell or taste, and sometimes the same insect emits two distinct odours from different parts of its body—one protective, and the other, perhaps, attractive.

Insects so voracious as caterpillars frequently commit great havoc in our fields and gardens. Perhaps the most formidable of all are those called "Cut-worms" in America, which live beneath the surface of the ground, and eat through the roots of plants which come in their way. Most of these develop into dark-coloured Moths, belonging to the genus *Agrotis*. As a set-off against the mischief caused by Butterflies and Moths, we have the valuable product called silk; and in some parts of Australia cakes formed of a particular species of *Agrotis* form a staple food of the inhabitants. We do not eat insects in Europe, but may derive much pleasure from studying their structure and habits, and from admiring their beauty.

Butterflies and Moths are found in all parts of the world, and are exceedingly numerous in species. There are about 2,000 different kinds in the British Islands, out of which only sixty-five are Butterflies and the remainder are Moths. Islands are always poorer in species than continents; and if we take Europe into consideration, we find 5,000 species of Moths, and nearly 300 of Butterflies on the lists. Iceland alone is said to produce no Butterflies, but only a few Moths, but both Butterflies and Moths (though not more than about a dozen different kinds) have been met with in the polar regions, as far north as our explorers have yet penetrated. Insects are far more numerous in the warmer parts of the world, abounding most where the vegetation is most luxuriant and varied. About 10,000 species of Butterflies and 40,000 of Moths have been described at present, and hundreds of new species are added to our lists every year. Butterflies are particularly numerous in tropical America, and more than half of all the species known inhabit this part of the world. Upwards of two thousand different kinds have been collected in the valley of the Amazon alone, but a great number of these are small and inconspicuous species, and it is the aggregate and not the comparative number of large and brilliant species which makes us consider size and colour as so characteristic of the Butterflies of the Tropics. If we compare two species belonging to corresponding groups, one of which is found in Europe or Japan, and the other in India, we shall generally find that the Indian insect is the smaller. Nor does the abundance of species depend on heat alone, but rather on the variety of the vegetation, and therefore Butterflies and Moths are far more numerous in Switzerland, where the variety of elevation gives rise to a greater variety of vegetation, than in the peninsulas of Spain or Italy. Andalusia, with its subtropical climate and vegetation, hardly produces more Butterflies than Sweden. Many of those which occur on the plains in Lapland are met with in the Alps in Switzerland; and many common Central European Butterflies are mountain insects in Andalusia, and the number of species peculiar to the extreme South of Europe is comparatively small, and by no means compensates for the almost total disappearance of the numerous Alpine species of Central Europe. The opposite coast of North Africa is even poorer in species than Southern Spain.

Before closing this chapter, some of our readers may wish for a few hints in regard to forming a collection of Butterflies and Moths. It is easy to make a beginning, and the utensils required are neither numerous nor expensive—a net, pins, setting-boards, and boxes being everything which is required in the first instance.

The most convenient kind of net is, perhaps, the ring-net. This consists of a net of green gauze, attached to a ring fixed on the end of a stick. The net should be gradually tapering, but rounded at the end, so as to contain no corners, and should be about three times as long as the width of the ring. It should not be sewn directly on the ring, but attached to a strip of some stouter substance at the

top, which can be sewn on the ring, for this will make the net last much longer. The ring should be about a foot in diameter, and it is usual to employ a jointed iron ring, which can be folded up when not in use and put in the pocket. It may be made to screw on the end of a common walking-stick, for which a cap must be provided, to screw on when the net is not wanted, to keep out the dirt. If a net is required in a hurry, it may simply be sewn on a ring of willow-twigs, and fixed at the end of a forked stick, and such an arrangement will answer very well on an emergency. A very portable but more expensive net is the umbrella-net. This is formed of a large ring of whalebone, with a stick through the middle. It is made to open and shut like an umbrella, and goes into a similar case when not in use; but it is too short for many purposes, and the stick in the middle is another objection.

Having caught your Butterfly or Moth, you next proceed to secure it. The pins used by entomologists are long and slender, and are sold by dealers in objects of natural history under the name of "Entomological pins," for those used for common purposes are generally too short and thick. The pins are made of different sizes; choosing one proportioned to the size of the insect, it must be pinned exactly in the middle of the thorax. You then pin it into a small box, lined with cork, which you carry in your pocket. But if you like to bring your specimens home alive, as can be done in the case of most of the smaller Moths, you must be provided with a supply of strong chip-boxes, into which to put your captures. You must take care only to put one insect into each box, and to keep the full and empty boxes in separate pockets, to avoid mixing them. But Butterflies, *Sphinges*, *Bombyces*, and, generally speaking, all large and active insects, must be pinned on the spot; for if you put them into a box they will knock themselves about in it, and when you open it you will find only a mass of fluff, and your specimen spoiled.

In putting these insects to death, of course the speediest means will be adopted. Small or slender-bodied insects, including most Butterflies, may be killed by a sharp nip under the wings, but this method will not answer for thick-bodied insects. These may be killed by being pierced with a pin dipped in a strong solution of oxalic acid, or may be stupefied with chloroform, and afterwards killed by being placed in a jar half filled with bruised laurel leaves, and tightly stoppered. Ammonia, sulphur, and cyanide of potassium, which some collectors use, are liable to discolour many insects. If you are on a journey, and short of boxes, you may keep your insects in "papers." These are constructed of square pieces of paper folded diagonally, and doubled over at the side, so as to form a triangular envelope open at one end. In this case the insect is simply killed and dropped into the envelope, which is then folded over and put away loosely in a box with cotton wool and a little camphor. But this method is not to be recommended when you are able to pin and set your insects at once.

In order to set your captures you will require setting-boards. These are proportioned in width to the size of the insects to be set, and may be of any convenient length; those most commonly used are about ten inches long. There is a corked groove in the middle to receive the body of the insect, and the sides are also formed of cork. The boards may be flat if you prefer it, as used on the Continent, but they are generally bevelled off on each side in England, which gives the wings of the insect a sloping appearance in the cabinet.

Having chosen a board proportioned to the size of the specimen you wish to set, you pin the Butterfly as nearly as possible in the middle of the groove. The body lies in the groove, and you then spread out the wings on each side in as natural a position as possible, and keep them in their places by pressing them down with strips of cardboard, secured by a pin at one or both ends. Only practice will enable you to do this neatly, and you will soon find that some insects are much easier to set than others.

It will sometimes happen that your specimens pinned in the field become too stiff to set properly when you get home. These, as well as any specimens which have been pinned or papered and left unset, will require to be relaxed. This is effected by putting them into any covered vessel partly filled with damp sand or sawdust, and placing them in a warm place. In a day or two they will become sufficiently limp to set, and must then be attended to at once, for if left too long they may become mouldy or rotten. In all cases insects must be left on the setting-boards till their wings have completely stiffened in the position which you have given them.

When the specimens are thus prepared they must be placed in store-boxes, or in cabinets made

for the purpose. The boxes or cabinet-drawers must be lined with cork, and the latter are usually provided with tightly-fitting glazed lids. Any box used for insects should be tightly-fitting, and furnished with plenty of camphor, or mites and other pests will soon reduce your collection to dust. Many preventives have been recommended, but camphor, plentifully used, and the supply well kept up from the first, appears to be the most successful of all. Butterflies in glass cases would form a very pretty ornament on the wall; but although they will preserve their colours for more than a century if kept in the dark, they bleach very rapidly if constantly exposed to the light.

You will find Butterflies and many Moths flying in gardens and other places where there are plenty of flowers, and these may be captured with the net. As it grows dusk the Butterflies disappear, but the Moths become more numerous, and they may be caught in the same way until it grows too dark. Later in the evening it is a good plan to daub over the trunks of trees with some sweet compound—a mixture of brown sugar and beer, flavoured with a few drops of rum, is most commonly employed—and afterwards visit the trees with a lantern and catch the Moths which are attracted by the bait. This mode of collecting is called "sugaring," and is somewhat uncertain, as on some nights the sugar will be covered with Moths, and on others you will scarcely find one.

In the country many Moths may be attracted by a light placed at an open window. During the day you will not see many Moths, except those which are habitually day-flying species, but if you look about a little you will sometimes find Moths sitting on the shady side of the trunks of trees, especially early in the day, and by beating a hedge to windward you will generally dislodge a great variety, chiefly slender-bodied or small Moths, which you can catch as they fly out.

There are no Butterflies to be found on the wing during the depth of winter, but there are several species of Moths which only appear at this season of the year, and a considerable variety may be caught in the evening, both in early spring and late autumn, at the blossoms of the sallow and the ivy respectively.

CHAPTER X.

BUTTERFLIES.

The Brush-footed Butterflies—Butterflies distasteful to Birds—Mimicry—Transparent-winged Butterflies of South America—Brown Butterflies frequenting Marshes and Meadows—Silvery Butterfly from Chili—The Great Blue Butterflies of South America—Great Owl-like Butterflies Flying at Twilight—An African Group of Spotted Butterflies—Passion Flower Butterflies of South America—The Fritillaries—The Comma Butterfly—Leaf Butterflies—Dissimilarity of the Sexes in some Butterflies—Red, Blue, and Green Butterflies of South America– Elegant Flight of the White Admiral—Lofty Flight of the Purple Emperor—Long-snouted Butterflies—A large Group of Small and Elegant Butterflies almost peculiar to South America—Copper Butterflies—Small Blues—Hairstreaks—Long Tails of some of the Allied Eastern Species—The White and Yellow Butterflies—Some of this Group Brightly Coloured—Mimicking South American Butterflies—Small and Large Yellow Butterflies of the Tropics—Garden Whites—White Indian Butterflies with Red Spots on the Under side—Indian Butterflies with the Front of the Wing Ridged like a Saw—The Brimstone and Clouded Yellow Butterflies—Orange-tips—Swallow-tailed Butterflies—The Apollo Butterflies—Magnificent Tailed Butterflies from the Himalayas—The Great Bird-winged Butterflies of the East—A Crœsus among Butterflies—South American Butterflies with Iridescent Spots—Mimicking Butterflies again—Gold-dusted Butterflies—Great Blue Butterflies of the Eastern Islands—The True Swallow-tailed Butterflies—Extraordinary Difference between the Sexes of an African Butterfly—Very Long Tails of a Small Indian Group—The Skippers—Their Resemblance to the Moths—Tailed Skippers of South America—The Fire-tailed Skippers—The Grizzled Skipper—The Pearl Skipper.

The first five families of Lepidoptera are called Butterflies in England, and their antennæ are nearly always thickened into a knob at the extremity. All the European species, and the great majority of the foreign ones, fly only by day, though some species prefer the shades of the forests, and some tropical Butterflies fly only at dusk. There is reason to believe that others fly more or less at night, but this requires to be confirmed by further observations.

FAMILY I.—NYMPHALIDÆ.

Half the known Butterflies belong to the first family, that of the *Nymphalidæ,* which is divided into several sub-families. The front legs of these Butterflies are rudimentary in both sexes, forming a

kind of paw, quite useless for walking, and hence some writers have called them Brush-footed Butterflies. The pupa is generally suspended freely by the tail. The caterpillars differ in structure, some being hairy or spiny, others furnished with long fleshy filaments, and others again are almost naked, with a forked tail.

The first group, the *Danainæ*, is almost confined to the tropics. Most of the species of *Danais* inhabit the Old World, though a few are met with in America, one species being abundant over almost the whole of that Continent. They are large broad-winged Butterflies, generally either of a warm reddish-tawny colour, with blackish borders, or brownish-black, the centre of the wings being green, divided by the veins. The only European species (*Danais chrysippus*) is found in Greece, but is also one of the commonest Butterflies in the East Indies and Africa. It is reddish-tawny, with black borders dotted with white, and the tip of the fore wings is broadly black, and marked with a band of large white connected spots. There are also four black spots in the middle of the hind wings. There is scarcely any Butterfly which is more interesting than this insect, as it illustrates some of the most remarkable problems of insect life in a pre-eminent degree. The *Danainæ* are rarely attacked by birds. Their integuments are exceedingly tough, and most of them possess the power of protruding two strongly-smelling processes from the abdomen. But it would scarcely be imagined beforehand that the colours and markings of a species thus protected would be repeated, with more or less accuracy, in six or eight other Butterflies and Moths, bearing a much closer resemblance to the species which they thus "mimic" than to any of their own allies. What is still more strange is that in several of these instances it is the female only which resembles the species "mimicked," the male being utterly different. The principal species which thus "mimic" *Danais chrysippus* are as follows:—(1) *Elymnias undularis*, belonging to the sub-family *Elymniinæ*. In this species the male is of a rich brown, with bluish marginal spots, while the female is tawny, with broad brown borders spotted with white on all the wings. On the fore wings the white spots coalesce into a band towards the tip. (2) *Argynnis niphe.* This species, which belongs, like the two following, to the sub-family *Nymphalinæ*, has a tawny or fulvous male, spotted with black, and resembles its allies, the ordinary Fritillaries; but the female is paler, with a black border and a broad black tip, crossed by a white bar like *Danais chrysippus*. *A. niphe* is a common East Indian species, but the Australian form (*A. inconstans*) has a female resembling the male. (3) *Hypolimnas misippus.* This case is

1, DANAIS CHRYSIPPUS; 2, HYPOLIMNAS MISIPPUS, MALE; 3, DO., FEMALE.

more remarkable than the last, for the male is of a rich brown colour, with a large white spot on each wing, shading into blue at the edges, while the female is scarcely to be distinguished from *D. chrysippus* at first sight, except that there is only one black spot instead of four on the hind wings. There is a species of *Danais* closely allied to *D. chrysippus*, in which the white transverse band at the tip of the fore wings is wanting (*D. dorippus*), and there is a variety of the female of *H. misippus* corresponding to it (*H. inaria*), in which the white band is also wanting. (4) *Euphœdra eleus.* Most of the species of this genus are green and black, but *E. eleus* is rich tawny, with black borders spotted with white, and a white bar across the tip of the fore wings. (5) *Papilio merope.* This Butterfly, which is a creamy-white Swallow-tail with black borders, is common in Africa, and the form found in Madagascar (*P. meriones*) has a female similar to the male, but no female resembling the male has ever been found on the continent of Africa, where the females are tailless Butterflies, resembling several different species of African *Danainæ*, and one of these (*P. dionysus*) has a close resemblance to *D. chrysippus.* (6) *Caryatis phileta.* This insect, a Moth allied to the *Lithosiidæ*, likewise reproduces the colours of *D. chrysippus*, being of a rich tawny, with black borders spotted with white.

EUPLŒA MIDAMUS: A, MALE; B, FEMALE.

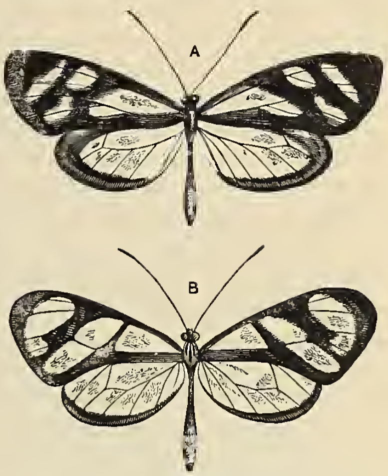
In addition to the scent-glands at the extremity of the abdomen, the males of most species of *Danais* and *Euplœa* possess a patch of raised scales on the hind wings, which is likewise a scent-producing organ.

The genus *Euplœa* is confined to the tropics of the Old World. The species are generally of a rich dark brown, with bluish-white spots near the borders of the wings and in the middle of the hind wings beneath, and are often splendidly glossed with purple. The wings are longer and narrower than in *Danais.*

With the exception of *Danais*, all the South American Butterflies now included in the *Danainæ* were formerly classed with the *Heliconinæ*, on account of their superficial resemblance to the genus *Heliconius.* They are insects with very long and slender bodies, and very long and narrow wings, and have sometimes been compared to Dragon-flies. The greater number of these Butterflies belong to the genus *Ithomia*, and a large proportion are more or less transparent, except on the borders of the wings. Some of these are mimicked by *Pierinæ.*

The second sub-family of the *Nymphalidæ*, the *Satyrinæ*, contains at least 1,000 species, but most of these are small or middle-sized Butterflies, of sombre colours. The great majority are marked with eye-like spots on the under surface of the wings, and sometimes on the upper surface also. Nearly one-third of the European Butterflies belong to this sub-family, but they are by no means so well represented in other parts of the world. Their caterpillars are generally green,

with a forked tail, and feed on different kinds of grasses. The Butterflies frequent marshes, meadows, and mountains, and many are among our commonest Butterflies, flying in every field. Many species of the genus *Erebia* are found in the Alps, the great majority of which are brown, with a row of more or less contiguous red spots towards the margins, marked with a series of black spots, which often, again, show a small white dot in the middle. The Scotch Argus Butterfly (*Erebiæ medea*) is the best known representative of this genus in Britain. Some foreign *Satyrinæ* are of a brilliant blue, though this colour is rare in the sub-family; but one of the most remarkable Butterflies known, as regards colour, is *Argyrophorus argenteus*, a Chilian insect, which is of a uniform pale silvery colour above.



A, LEPTALIS THEONOË; B, ITHOMIA FLORA.

The small sub-family of the *Elymniinæ* consists of the two genera *Elymnias* and *Dyctis*. We have already noticed the female of *Elymnias undularis* as one of the mimics of *Danais chrysippus*. All the species of *Elymnias*, except two, which are African, are East Indian or Malayan. They are generally dark-coloured insects, averaging about three inches in expanse; the fore wings are often spotted with blue and white, and the hind wings are bordered with orange. Most of the species are striated with brown on the under side, and the group has a strong family likeness, which renders it easy to recognise it. Nearly all the *Elymniinæ* mimic other Butterflies in the arrangement of their colours on the upper side of the wings, but their wings are always dentated, and often angulated, whereas all the Butterflies which they superficially resemble have rounded wings.

EREBIA EURYALE.

The next sub-family, the *Morphinæ*, though including some conspicuous East Indian species, is best represented by the typical genus *Morpho*, which contains the magnificent blue Butterflies of South America. The most brilliant of all known Butterflies is, perhaps, the male of *Morpho cypris*, a dazzling sky-blue Butterfly, five inches in expanse, which can be seen at the distance of half a mile in the sun. A white band across the centre of the wings only enhances its beauty. The female sometimes resembles the male, and sometimes, as is often the case in *Morpho*, is of a tawny or orange colour. Some of the species of *Morpho* fly near the ground, and frequently settle, but nearly all the largest and most splendid species fly at a great height.

MORPHO CYPRIS (MALE, TWO-THIRDS NATURAL SIZE).

The next sub-family, the *Brassolinæ*, consists entirely of tropical American species, but these are dull-coloured Butterflies, which fly at dusk. The great Butterflies of the genus *Caligo* resemble *Morpho* in size and appearance, but are brown, with the upper side of the wings suffused with dull blue. The under surface is curiously marbled and speckled with brown and grey, and on the under side of the hind wings is an enormous oval dark spot, in a broad pale ring, resembling an owl's eye.

The sub-family *Acræinæ* chiefly contains African species of the genus *Acræa*, though one or two inhabit India or Australia, and the genus *Actinote* is South American. The wings of the *Acræinæ* are

rather long, and are generally of some shade of fulvous, with black spots, or black with white or yellowish markings; and the hind wings are either striated or spotted with black at the base beneath. Although these Butterflies are not closely allied to our European Fritillaries, yet they completely replace them in Africa, resembling them not only in colour and appearance, but also in the spiny larvæ. The fore wings of several species of *Acræa* are more or less transparent; in others the wings are entirely opaque. In *Actinote* the wings are always opaque, and destitute of the black basal spots so conspicuous in *Acræa*, but the hind wings are always strongly striated, at least on the under surface. The colouring, too, in one section of this genus is very dissimilar to that of *Acræa*, being bluish-black, with the centre of the fore wings pink or red, this colour sometimes extending to the base.

The *Heliconinæ* are a group of South American Butterflies, much resembling the *Acræinæ* in structure, but their wings are much longer, and are generally rounded at the extremity. Their closed wing-cells will prevent their being confounded with the typical *Nymphalinæ*, and although some of them closely resemble the American *Danainæ*, which were formerly classed with them, the submedian nervure of the fore wings is simple in the *Heliconinæ*, and double in the *Danainæ*. Their caterpillars are spiny, like those of the *Acræinæ*, and many of them feed on different species of passion-flower.

The genus *Heliconius* includes a great number of beautiful species. Some are black, with a large red blotch on the fore wings. Sometimes this is the only marking, as in *H. melpomene;* but in other species the hind wings are rayed with red, or marked with a basal stripe of yellow or white. In other species the fore wings are marked with yellow, and the hind wings are red, or banded with red. *H. charithoniæ*, the commonest species in the West Indies, is black, with yellow stripes on the wings; other species are black and fulvous, spotted or banded with yellow, and many of these resemble some of the larger opaque species of American *Danainæ*, both in colour and markings.

The species of *Heliconius* vary from two to four inches in expanse, and the antennæ are long and slender. The only other genus of this sub-family (*Eueides*) has much shorter antennæ, and the species, which are generally black and tawny, varied with dull yellow, seldom exceed an inch and a half in expanse.

The great sub-family of the *Nymphalinæ*, which comprises about 130 genera of Butterflies, exhibiting every variety of colour and pattern, differs from all the foregoing groups, except the *Morphinæ*, by the discoidal cell being open, or imperfectly closed, either in all the wings or in the hind wings only.

The first two genera, *Colænis* and *Dione*, are long-winged South American Butterflies, the caterpillars of which feed on passion-flowers, vanilla, and other tropical plants. They resemble the *Heliconinæ* considerably in size, shape, and habits, and form a very good connecting link between these and the *Nymphalinæ*; and some entomologists regard them as more properly belonging to the former sub-family. The species of *Colænis* are fulvous above, more or less banded with black. On the under surface they are either coloured as above, or are indistinctly marked. One species (*Colænis dido*) is of a most beautiful green, with black markings above, and brown and silvery markings below. *Dione juno* resembles the genus *Colænis* in shape, but most of the species of the former genus have much shorter and broader wings. They are rich fulvous, spotted or veined with black, and the hind wings and the tips of the fore wings are literally covered with large silvery spots beneath.

The East Indian genus *Cethosiæ* includes a number of closely-allied and very similar species, which may be distinguished at once from any other Butterflies by their elegant festooned black and white markings, especially on the under surface of the hind wings. They somewhat resemble *Danainæ*, being tawny above, with black, white-spotted borders, and some species appear to mimic *Danais chrysippus*, &c.

The true Fritillaries are well known to all collectors of Butterflies. The genus *Argynnis* is well represented throughout the Northern Hemisphere, but there are none in Africa, beyond the Mediterranean district, nor in South America, except one or two small species in the Andes or in Chili. There are six beautiful species in England, all fulvous, with black spots and streaks above, and more or less spotted or streaked with silver on the under surface. In the North Chinese *A. sagana* the male

resembles *A. paphia*, while the female is olive-green marked with white, and might well be supposed to be allied to *Apatura* or *Limenitis*. A new genus was actually formed for its reception when it was first discovered. Among the most striking of the North American species are *A. diana*, with a black male, broadly edged with orange, and a green female, spotted with whitish, and *A. idalia*, one of the largest Butterflies of the genus, which has reddish fore wings, and blackish hind wings, with two rows of whitish spots above. The caterpillars of *Argynnis* are spiny, and mostly feed on different kinds of violets.

Melitæa is another genus of small Fritillaries, of which we have three representatives in this country. They are tawny, with black lines and spots above, and the under side of the hind wings is more or less banded or chequered with yellowish or reddish, being marked with black lines, and sometimes spots. All our species are very local, though common where they occur. Several others are found on the Continent, two of which are black with white markings; but the greatest variety and the largest known species of *Melitæa* are to be met with in California. Many of these are black, with transverse rows of yellowish spots, sometimes alternating with reddish ones.

TRANSFORMATIONS OF QUEEN OF SPAIN FRITILLARY (*Argynnis lathonia*).

The European species of *Vanessa*, &c., are less numerous than the Fritillaries, but present a much greater variety of colour and markings. Their larvæ are spiny, and feed on nettles, thistles, elms, willows, &c. The smallest species of this group, though common on the Continent in damp woods, is not British. This is *Araschnia prorsa*, a Butterfly which exhibits the phenomenon known as "seasonal dimorphism" in its greatest perfection. It expands less than an inch and a half. The hind margins of the fore wings have two slight projections, and the hind wings have one projection in the middle, making the outer margin nearly rectangular. The spiny black caterpillar, which is sometimes striped with brown, lives gregariously on nettles. The spring brood of the Butterfly is found in April and May. It is fulvous, spotted with black. There are three white spots near the tip of the fore wings, and rows of black spots across all the wings. The under surface is brownish-red, varied with violet and pale yellow, with pale yellow veins and transverse lines. But the summer brood of the same Butterfly, which is met with in July and August, is utterly different, and until the specific identity of the two was proved by breeding and observation, it was naturally supposed to be a totally distinct species. It is black, with a red marginal line, and a white transverse band, which is interrupted on the fore wings. The under side is redder than in the spring brood, with white instead of yellow markings. Intermediate varieties are occasionally met with. This Butterfly is called "the Map" in France and Germany, probably in allusion to the character of the markings on the under surface of the wings.

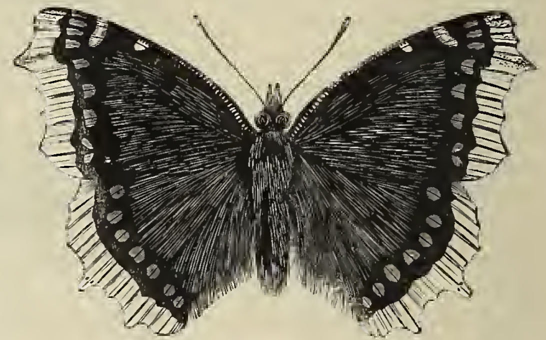
The Comma Butterfly (*Vanessa C-album*) has strongly dentated wings, more so than any other British Butterfly, giving it at first sight the appearance of being very tattered. It is of a deep fulvous, with dark brown spots and borders. The under surface is brown, black, greyish, or greenish, but the hind wings are always marked with a white C beneath. There is only one other species of

this section of the genus in Europe, but in North America there are several, all very similar to the insect we have just described. Although local, the Comma is not unfrequently met with in many parts of England, but it is the least common of our British species of *Vanessa*, except the large chocolate-coloured, yellowish-bordered Camberwell Beauty (*Vanessa antiopa*), which, although abundant in America, as well as in many parts of Europe, is a great rarity in England, but like many other Butterflies is met with much more frequently in some years than in others.

THE COMMA BUTTERFLY.

It has lately been noticed by various observers that the Small Tortoiseshell and Peacock Butterflies (*Vanessa urticæ* and *V. io*) have the power of stridulating, or producing a sound which has been compared to the friction of sandpaper. The credit of discovering the apparatus which causes the sound is due to Mr. A. H. Swinton. The hinder vein of the fore wings is bare of scales at the base beneath, and serrated, and this works upon the front vein (or costal vein, as it is called) of the hind wings, which is likewise bare, smooth, and curved outwards at the base.

The elegant brick-red, or pale salmon-coloured Painted Lady Butterfly (*Pyrameis cardui*), is the last European species of this group which we shall notice. The caterpillar feeds on thistle, and the Butterfly is generally common in waste places at the end of summer, not in England only, but over a great part of the world. It is much commoner in some years than in others, and is occasionally sufficiently numerous to migrate in vast swarms from one district to another.



THE CAMBERWELL BEAUTY.

Among the commonest and most widely distributed of the exotic Butterflies allied to *Vanessa* are those of the genus *Junonia*. As now restricted, it includes several species with smooth eyes (those of the *Vanessæ* are hairy), and with slightly dentated wings. They are insects about the size of our *Vanessa urticæ*, and the wings are black, brown, or grey, generally adorned with two eyes on the hind wings, and one towards the hinder angle of the fore wings. Several species are common in every collection of insects from the East Indies. *J. laomedia* is of a slightly iridescent grey, with transverse zigzag brownish lines, and a row of rather small eyes beyond the middle, of which two towards the tip, and one towards the hinder angle of each wing, are more distinct than the others, and consist of an outer brown ring, an inner grey or buff one, and a black pupil surrounded with orange. Although the East Indies form the head-quarters of the genus *Junonia*, several species closely allied to the Indian ones are met with in Africa and America.

THE SMALL TORTOISESHELL BUTTERFLY.

The genus *Precis*, formerly included in *Junonia*, comprises many beautiful African Butterflies, and one or two Indian species also. The wings are generally dentated, the fore wings more or less angulated, and occasionally almost hooked, and the hind wings often produced at the anal angle. Instead of large eyes on the wings, as in *Junonia*, there is sometimes a marginal row of small ones on the hind wings. The beautiful blue *P. rhadama* of Madagascar, however, has eyes placed as in *Junonia*. The species of *Precis* are generally brown, sometimes almost without paler markings, but more frequently banded with some shade of fulvous, and occasionally with blue or red.

The genus *Kallima* is one of the most remarkable of the *Nymphalinæ*, from the extraordinary resemblance of the under surface of the insect to a dead leaf. The Indian species are nearly four inches in expanse, bluish or purplish above, with a small transparent spot in the middle

of the fore wings, beyond which a broad orange band in some species, or a bluish-white one in others, runs obliquely from the middle of the costa, or front edge of the fore wings, nearly to the hinder angle. The fore wings are more or less pointed, and the anal angle of the hind wings is produced into a short blunt tail. The under surface is brown, with a dark streak resembling a mid-rib running from the tip of the fore wings to the tail of the hind wings. The surface is irregularly streaked and mottled, and Mr. A. R. Wallace describes the Sumatran *Kallima paralekta* as being invisible when at rest, from its resemblance to the dead leaves among which it always perches. The Butterfly sits with its wings over its back, and its head and antennæ raised and hidden between them, while the tails of the hind wings rest upon the branch, corresponding exactly in appearance with the stalk of the leaf.

The genus *Eunica* contains a number of moderate-sized species. They are nearly all Tropical American Butterflies, of a brown or velvety black colour, and are often more or less suffused with blue, purple, or violet. One species (*E. margarita*) is silvery white above, with the tip black, spotted with white, and a double row of dark spots on the borders of the hind wings. The outline of the wings in *Eunica* is very various, but is generally dentated, and the tip of the fore wings is often truncated. The under side of the hind wings is always marked with a row of eyes beyond the middle, but this varies very much in distinctness.

LEAF-BUTTERFLY OF INDIA (*Kallima inachis*).

The South American genus *Catonephele* is very remarkable for the great difference between the sexes, for the females are so unlike the males that they were not only regarded as different species, but were even placed in different genera for many years. Thus the male of *C. obrinus* is black, with a broad blue band across the fore wings, and a broad orange band across the hind wings. The female is brown, with an additional blue spot near the tip of the fore wings, and one or two red spots, bordered with black, towards the base. The hind wings have three obscure narrow black stripes, the outermost sometimes marked with one or two blue spots.

The handsomest of the smaller South American *Nymphalinæ* are probably those belonging to the genus *Catagramma* and its allies. The first of these is the genus *Callicore*. The species are all of a rich dark brown or black above, and the fore wings, which are often suffused with purple towards the base, are crossed by a bar of changeable bluish-green, blue, or purple. The hind wings are generally bordered by a metallic green or blue stripe. The under surface of the fore wings is of a rich scarlet towards the base, followed by a curved black band, varying in breadth, and the tip is silvery white, or buff, intersected by a black line. The hind wings are silvery white or buff, with two oval black rings in the centre, each of which contains two black spots, varying in size, and sometimes connected. These are enclosed by two large black rings, which run round the whole wing, except on the costa, where the circle is not complete.

The genus *Perisama* much resembles *Callicore* in size and shape, but the band of the fore wings is frequently incomplete, and combined with more distinct basal stripes. The fore wings are black beneath, generally spotted with blue, with the tip pale, and intersected by a black line, and the basal portion is frequently more or less broadly red or yellow. The under side of the hind wings is yellow, silvery white, or buff, and is nearly always crossed by two black lines, widest apart in the middle, between which runs a row of black dots.

The genus *Catagramma* resembles the last two genera, but the eyes are naked instead of hairy. There are a great number of species, differing very much in colour and markings, and the name alludes to the elegant markings of the under surface, meaning "written beneath." These Butterflies are of a deep black, adorned with rich shades of crimson or orange on the upper side, and are frequently glossed with purple over the black, and sometimes over the crimson. In some species the sexes differ little; in others, the males are crimson and the females orange, or even, occasionally, black above. But the sexes differ much in their habits. The females generally live a retired life in the forests, and are often very rare, even when the males are abundant. There are a great number of species, all with a strong family likeness, though more varied in colour above and in patterns below than either of the two preceding genera. The pattern of the under side of the hind wings varies very much in different species. Sometimes they may be striped with black and yellow, or the centre may be black with an irregular row of blue spots, or the centre may be yellow, enclosing two large black spots, each marked with a variable number of eyes.

Callithea, the most splendid genus of the *Catagramma* group, contains larger species, found towards the west of South America. In *C. sapphira* the male is of the richest blue, while the female is blue only at the base, followed by a broad transverse orange band in the fore wings, while the hind wings are bordered with dull green. Some of the other species are similarly marked, while others are bluish-black towards the base; and a pale bluish band runs round the borders of all the wings. The under side of all the species is green, sometimes more or less broadly orange at the base, and marked with transverse rows of black spots or lines.

Batesia hypochlora, and its allies or varieties, are also large and splendid insects, from the Upper Amazons and Ecuador. The fore wings are black, with the basal third blue, and a very large red oval transverse spot or band running nearly across them. The hind wings are blue above, with a rather narrow black band near the border; and beneath they are olive-yellow, or greenish.

The genus *Ageronia* contains many common and well-known insects from Tropical America. These Butterflies frequent forests, and their habits were studied by Mr. Darwin. He met with *A. feronia* in the orange groves of Brazil, and describes it as a high flyer, but fond of alighting on the trunks of trees with its head downwards. It is remarkable for using its legs for running, but still more so for the clicking or crackling sound produced by the wings during flight. Mr. Darwin's observations have been subsequently verified by other naturalists, and the stridulation proves to be common to both sexes. It has not yet been ascertained whether the sound is produced at rest as well as when flying. Although several other Butterflies are now known to stridulate, yet this species is interesting as being the first on which this observation was made.

The species of *Ageronia* expand from two to three inches. *A. feronia* and its allies are mottled with black, bluish, and white, and are sometimes marked with dull reddish spots; and there is generally a sub-marginal row of black eyes with white pupils on the hind wings. Other species are velvety-black above, spotted with blue, or very deep blue, spotted with paler, and with an oblique white band in the fore wings in the females. The under surface of the hind wings may be pale silvery-grey, with a row of submarginal brown rings, bordered on each side with a brown line, or may be yellow, red, brown, or steel-blue spotted with red, in various species.

Cyrestis includes several delicate Butterflies confined to Tropical Asia and Africa. The hind wings are generally produced into a lobe at the anal angle, and there is a short projection or tail at the lower part of the hind margin, where the wing is angulated. Some of the species are white, marked with transverse dark or yellow lines towards the base; others are tawny, with dark lines, or dark brown, with a transverse band of white.

Cyrestis is represented in South America by the genus *Megalura*, which is remarkable for the superficial resemblance which the species bear to the true *Papilioninæ*, or Swallow-tailed Butterflies,

from which, however, they may be at once distinguished by their imperfectly developed front legs. They are brown, tawny, or yellowish-white, marked with slender transverse lines, most conspicuous on the under side, which is generally of a paler colour. There is a lobe at the anal angle of the hind wings, and a long tail at the lower part of the hind margin. There is another group with much longer wings, somewhat resembling the tawny species of *Colænis* in colour, size, and shape, except that there are three tails on the hind wings, that in the middle being the longest.

A, ACRÆA GEA; B, PSEUDACRÆA HIRCE.

We have already spoken of *Hypolimnas misippus*, and the extraordinary resemblance of the female to *Danais chrysippus*. Several of the smaller species of *Hypolimnas* resemble the genus *Euplœa*, but others are among the largest and handsomest of the Butterflies inhabiting Asia and Africa. One of the commonest African species is *H. salmacis*, which averages four inches in expanse. It is a dark brown Butterfly, broadly banded with white and blue. An African genus allied to this is called *Pseudacræa*, from the great similarity of several of the species included in it to those of the genus *Acræa*.

The White Admiral (*Limenitis sibylla*) is a black Butterfly with white markings, and is considered a rather scarce insect in England. Its elegant sailing flight has long been celebrated; and Haworth tells a story of an old entomologist who was too infirm to chase Butterflies any longer, but who would sit for hours together on a stile which commanded a view of a spot much frequented by this Butterfly, for the pleasure of watching its graceful evolutions on the wing. There is another European species of *Limenitis* (*L. camilla*), which is more sharply marked than ours, and is of a bluish-black. It appears rather later in the summer, and I have generally met with it flying round detached bushes, rather than in woods. The larvæ of both these Butterflies feed on honeysuckle. Many handsome species of *Limenitis*, differing very much from ours, and generally much larger, are found in India and North America.

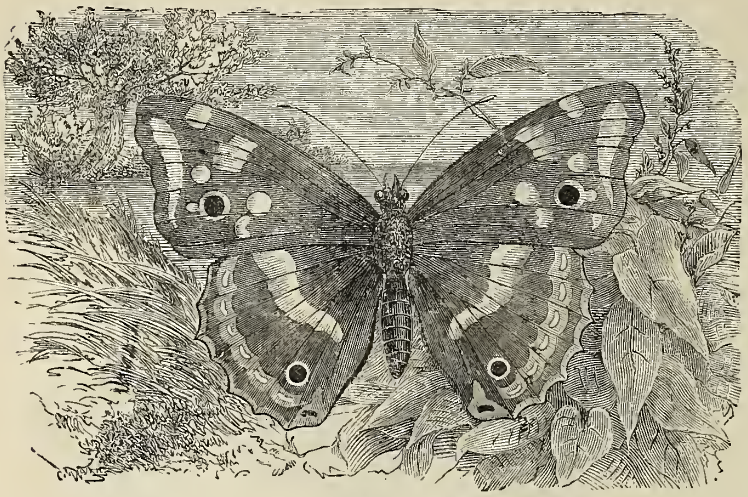
Neptis and *Athyma* are genera closely allied to *Limenitis*. The species are very numerous in the East Indies, but a few are African, and two species of *Neptis* are European. They are dark brown Butterflies, with a white streak, often divided into two or three, running from the base of the fore wings. Rather beyond the middle of the fore wings is a transverse white band, more or less divided into spots, and more widely interrupted in the middle of the fore wings. Towards the margins is an outer row of smaller white markings. This general description will apply to almost all the species, except that the white markings are often replaced with tawny.

THE WHITE ADMIRAL.

Hamanumida dædalus is a common African Butterfly, not remarkable for its beauty, but curious for its resemblance in colour to a Guinea-fowl, being grey, with several rows of white spots, edged with black. The under surface is more yellowish, but varies a good deal in intensity of colour. The obscure colouring of this insect must make it very inconspicuous, especially as the variations are said to correspond to the colour of the soil in the district where they occur.

The splendid genus *Apatura* includes the Purple Emperor (*A. iris*), one of the finest of our

British Butterflies. It measures from two to more than three inches in expanse, and is of a dark brown above, spotted and barred with white, and there is a red ring near the anal angle of the hind wings. In the nearly allied Continental *A. ilia* there is a similar eye on the fore wings as well. The male is shot with rich purple, and is remarkable for his lofty flight, usually perching on the tops of the tallest trees. It is common in Central Europe, but is confined to the south-east of England. Although ordinarily very difficult to capture, it will sometimes descend to the ground to drink at a puddle, or may be attracted by carrion. The caterpillar, which feeds on sallow, is green, with two horns on the head.



APATURA ILIA.

Aganisthos odius is a grand South American Butterfly, measuring five inches across the wings. The fore wings are long, and almost hooked at the tip, and the body is unusually stout. The wings are of a rich black, with the basal third of the fore wings tawny, this colour projecting in a large, slightly-curving lobe, almost to the hind margin. It is a Butterfly of very powerful flight, and that of *Prepona*, an allied South American genus, is said to be so rapid that the eye can scarcely follow it. Sometimes these Butterflies perch suddenly on the trunks of trees, closing their wings and remaining immovable. But if alarmed they dart away for a moment, and then return suddenly to the same spot. These Butterflies are similar in shape to our Purple Emperor, but much larger, and with much stouter bodies. They are black, with a broad bluish-green band across both wings, which is divided, contracted, and turned inwards towards the tip of the fore wings. The upper side of most of the species of *Prepona* is similar to this, the under side is brown or grey. Near to this genus, and almost as large, measuring over three inches in expanse, is another South American genus (*Agrias*), which resembles a gigantic *Catagramma* in appearance. *A. ædon* is brown, with a broad transverse scarlet band across the fore wings, and a large blue blotch near the anal angle of the hind wings. *A. phalcidon* is dark blue, broadly bordered with green.

CHARAXES JASIUS.

Charaxes is a genus almost confined to Asia and Africa, though one species (*C. jasius*), which feeds on the Arbutus, is found all round the shores of the Mediterranean. It is a large Butterfly, expanding about three inches. The body is stout, the border of the fore wings is deeply excavated, and the hind wings are dentated, with two rather long tails. It is of a dark brown above, bordered with deep orange ; and the under side is red, banded with white and orange, and marked with black spots, edged with white. It is a Butterfly of very powerful and rapid flight, turning about like a Swallow to avoid any obstacle. It is very shy, and delights in the hottest localities, avoiding the shade of deep woods, and preferring dry hills or the dry beds of torrents, up and down which it courses without stopping to rest. But like other

Nymphalinæ, it has a great preference for the same spot or twig, to which it will return day after day. It is fond of strongly-smelling substances, and rotten cheese is sometimes employed as a bait to attract it.

Protogonius, the last genus of *Nymphalinæ* which we shall notice, is South American. It is remarkable for its colouring, which resembles that of some of the *Heliconinæ*, as well as for its peculiar shape, which is unlike that of any other insect. *P. hippona* measures about four inches across the fore wings, which are much longer than the hind wings. They are black, with a large tawny blotch running from the base to the middle, and widest on its lower side. Beyond this is an irregular transverse yellow band, and nearer the tip a white spot. The hind wings are tawny, and their lower border is black, with a row of long white spots. The long fore wings are strongly arched, curving over to the tip, which is pointed, but not long, and followed by a concavity, below which is a longer and sharper projection; and another concavity brings us round to the hinder angle of the fore wings. At the outer angle of the hind wings is a long linear tail.

FAMILY II.—ERYCINIDÆ.

This family is intermediate between the *Nymphalidæ* and the *Lycænidæ*, for while the front legs are perfect in the females, they are rudimentary in the males. It is divided into four sub-families, of which the first, the *Libytheinæ*, containing only one genus and a very few species, has much resemblance to the *Nymphalinæ*, but may be distinguished from almost all other Butterflies by the enormous length of the palpi, which are four times as long as the head, and are contiguous throughout their whole length, forming a kind of beak, as in the *Crambidæ*. The fore wings have an angular projection below the tip, and the hind wings are dentated. One species is found in South Europe, which is brown, with a fulvous basal streak and large fulvous blotches. It measures about an inch and three-quarters across the wings. Several other species closely resembling this are met with in Asia, Africa, and America, and a blue species is found in the Moluccas. The pupa is suspended by the tail, as in the *Nymphalidæ*. The three other sub-families, forming the *Erycinidæ* proper, have very short palpi, and their pupæ are attached by the tail, and by a silken belt round the body as well. Very few species are met with out of South America, where they are exceedingly numerous, and are insects of rather delicate texture, unfitted for strong and sustained flight, and fond of settling on leaves rather than on flowers.

The second sub-family—or the first of the true *Erycinidæ*—is that of the *Nemeobiinæ*, and is distinguished by the subcostal nervure of the fore wings dividing into four branches instead of three. To this group belongs our British Duke of Burgundy Fritillary (*Nemeobius lucina*), which has a superficial resemblance to a small *Melitæa*. It is a local insect in the South of England, and measures about an inch across the wings, which are brown, and marked with rows of dull orange spots. On the under surface it is reddish-brown, with black marginal dots, and two rows of whitish spots on the hind wings. The East Indian species of *Nemeobiinæ* are larger and handsomer Butterflies, and the hind wings are either rounded and dentated, or end in a lobe, or short, blunt tail, or are square, with a projection at the outer angle. They are generally streaked or spotted with white on the under surface. The principal South American genus of this section is *Mesosemia*, to which belong a great number of little brown or b ue Butterflies, marked with black lines, especially on the hind wings, and nearly all have a large round black spot in the middle of the fore wings, marked with two or more white dots.

The *Euselasiinæ* only include one genus of importance (*Euselasia*). Their neuration is irregular, but the discoidal nervure is so closely united to the sub-costal nervure that it appears to be an additional branch, or a continuation of the sub-costal itself. This is difficult to explain in words, but the Butterflies themselves may be easily known, having rather short fore wings and long hind wings, often marked with lines or eyes on the under side. Some are brown, some blue, and others again are fulvous, and several species strongly resemble the small South American *Satyrinæ* of the genus *Euptychia*.

The last sub-family, the *Lemoniinæ*, contains species with only three branches to the sub-costal nervure, and with the sub-costal and discoidal nervures completely distinct. We need notice only a few of the principal genera. The species of *Limnas* have rather long fore wings, often with crimson

spots at the base. They are generally black, with orange borders or markings. The species of *Necyria* and *Ancyluris* are among the most beautiful of the group. They are black, with red or blue stripes, and the hind wings are often prolonged into a lobe, or a short tail. They are comparatively large Butterflies, expanding nearly two inches across the wings. *Zeonia* includes smaller Butterflies, with transparent wings, the blush veins and borders excepted. The hind wings are marked with red, and terminate in a long narrow tail. *Helicopis* includes some very delicate cream-coloured Butterflies, with three tails on the hind wings. They are varied with black or yellow above, and the under surface of the hind wings is spangled with metallic golden spots, as is also the case with several species of allied genera.

The species of *Emesis* are mostly very dull, dark brown Butterflies, with darker transverse lines, and the fore wings slightly pointed. The under surface is lighter, being dull brownish-yellow, or ochreous. *Mesene* includes a number of small red Butterflies, not expanding more than an inch across the wings, generally with black borders, or black markings on the costa of the fore wings.

A very characteristic and easily recognisable genus is *Nymphidium*, the species of which are nearly all white, with the costa of the fore wings and all the borders more or less broadly brown, and frequently marked with red lines or spots on the borders. Several long-winged genera have very little resemblance to the group to which they belong, but are more like species of *Ithomia*, or the allied genera. Such are some of the species of *Stalachtis*, *Ithomiola*, &c., while *Chamælimnas* includes a number of Butterflies with a lemon-yellow basal stripe, and a transverse band of the same colour near the tip of the black fore wings, and the hind wings are yellow, with black borders. These closely resemble an extensive group of day-flying Moths, also South American, both in shape, size, colour, and markings.

Passing on from this large group of delicately-marked, but rather uninteresting Butterflies, we come to another extensive and more familiar family of small Butterflies.

FAMILY III.—LYCÆNIDÆ.

In this family we find the legs of the males nearly as well developed as those of the females, except that they are rather smaller, and the last joint of the tarsi terminates in a simple hook. Their larvæ are short and stout, somewhat resembling a Woodlouse in shape.

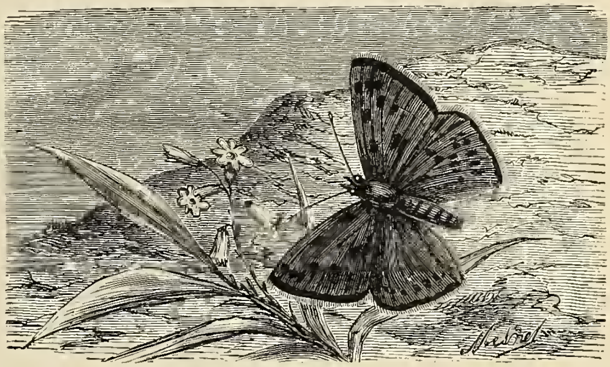
The great majority of these Butterflies are of small size, the largest seldom expanding more than an inch and a half or two inches, and the prevailing colours are blue, copper-red, or brown. The under surface is generally marked either with black eyes enclosed in pale rings, or with pale transverse lines; and the hind wings frequently end in a short and slender tail. This family is well represented in all parts of the world, especially in the Northern Hemisphere and in South America; but the number of distinctly defined genera is small, although the species are very numerous.

Miletus symethus is a small brown Butterfly, with a white spot on the fore wings, and a grey under surface, marked with obscure lines. It is common in the East Indies, and its legs are unusually stout; but what is much more remarkable is that it is said to inhabit Ants' nests. Strange as this habit is, it is by no means unexampled, for it is well known that a great variety of insects do inhabit Ants' nests, and among them is a small Scottish Moth (*Tinea ochraceella*), belonging to the same genus as the Clothes' Moths.

LYCÆNA PHLÆAS.

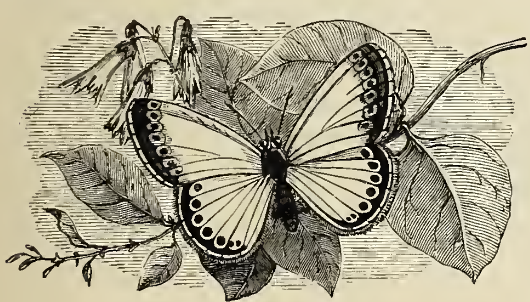
The species of *Zeritis* are red, with brown borders, and with metallic spots on the under surface of the hind wings. They are found in Africa, but do not equal the splendid colouring of our European Copper Butterflies of the genus *Lycæna*. The Small Copper (*L. phlæas*) has bright coppery-red fore wings, with black spots and borders, and the hind wings are black, with a marginal copper band. It abounds almost everywhere in dry, sunny, flowery places, and is found throughout Europe, North Africa, Northern and Western Asia, and a great part of North America. It is a pugnacious little Butterfly, often attacking and driving away much larger insects, if they approach the flower on which it is resting. The caterpillar is green, with red lines on the back and sides, and feeds on sorrel.

Another species (*Lycæna dispar*, the Large Copper) used to be common in the fens of the Eastern Counties of England. It expands about two inches, and the male is brilliant copper, with rather narrow black borders, and two spots in the discoidal cell of the fore wings. The female has copper-coloured fore wings, with three discoidal spots, and an outer row of large black spots. The hind wings are dark brown, with black spots, and a submarginal copper band, and are bluish-grey beneath. The caterpillar used to feed on the great water-dock, but the insect has not been seen alive in any stage for the last quarter of a century, and is believed to have become quite extinct in consequence of the draining of the fens. *L. dispar* is the largest species of the genus; yet the males of some others surpass it in the brilliancy of their colouring, and in some instances the copper is strongly glossed with blue or purple, as, in *L. gordius*, for example. But these species are not British, though common in some parts of the Continent.



LYCÆNA GORDIUS.

The small blue Butterflies, so familiar to all residents in the country, belong to the genus *Polyommatus*,* so called from the majority of the species being decorated with numerous "eyes," or black spots in white rings, on the under surface of the wings. In most of the species the males are blue and the females brown, but in some cases both sexes are brown, and some few species are white. But we have no white species in England, nor have we (except *P. bæticus*, as an occasional visitor) any representative of the section of the genus in which the hind wings are furnished with a short tail. The Common Blue (*Polymmatus icarus*) is a Butterfly about the size of the Small Copper, and of very similar habits. The male is lilac blue, with white fringes, and the female is blue or brown, with a marginal row of red spots. The under surface is brownish-grey on the fore wings, and yellowish-brown on the hind wings, with a marginal row of red spots, bordered with black ones, and a central row of eyes. There are also two or three spots nearer the base both on the fore and hind wings. In the Clifton Blue (*Polyommatus adonis*) and the Chalk-hill Blue (*P. corydon*) the fringes of the wings are spotted with black. The males of these insects are bright sky-blue and pale-blue respectively, and, like most of the British species of the genus, they are common on the chalk in the South of England. The Azure Blue (*P. argiolus*) is found in woods, flying about holly trees, but is not common everywhere. The male resembles the Common Blue above; the female is blue, with broad brown borders to the fore wings. The under surface is pale blue, with a central row of small black spots. The Silver-studded Blue (*P. ægon*) is common on heaths, and much resembles the Common Blue, but the outermost of three rows of black eyes on the under side of the hind wings is conspicuously dusted with bright metallic blue. Throughout this group of Butterflies the species are best to be distinguished by the colour and markings of the under side of the hind wings. In some Continental species, the upper side of which differs little from that of English species, the hind wings are green beneath, or brown with large white spots. The caterpillars of these Butterflies generally feed on vetches, trefoil, and similar plants, and a singular discovery has been made respecting them in America. They exude a liquid from their bodies of which Ants are very fond, and these attend upon them for the sake of it as they do upon the *Aphides*. This



POLYOMMATUS CORYDON.

* Many-eyed.

is an indirect confirmation of the statement which we have already mentioned, that *Miletus symethus* is found in Ants' nests.

The genus *Hypochrysops*, which is confined to Australia and the Malay Archipelago, contains blue or orange Butterflies, rather larger than the species of *Polyommatus.* The hind wings are dentated, but are chiefly remarkable for the gaudy colouring of the under surface, which is red in some species, with yellow and silvery spots, while it is banded with green and brown, or red, green, and yellow, and intersected with silvery lines, in others.

The genus *Thecla*, which includes the Butterflies known as Hair-streaks, except the group to which the Brown and Purple Hair-streaks belong, is the largest in the family. There are probably six hundred species known at present, but it is likely that they will ultimately be divided into smaller genera. *Polyommatus* is not quite so large a genus, but is more compact.

These Butterflies are exceedingly numerous in tropical America, but are poorly represented in other parts of the world, and are not found at all in Africa (except on the Mediterranean coast) nor in Australia, where they are replaced by other genera. They are generally rather small Butterflies, of a blue or brown colour above, and with a short tail on the hind wings. The under surface is brown, grey, or white, and often marked with pale lines, whence the Butterflies derive their name of Hair-streaks. There is often an orange spot above or below at the anal angle of the hind wings. The White Letter Hair-streak (*Thecla W album*), a rather uncommon species in England, is brown above, and the under surface is paler, and marked with a very distinct white line across all the wings, forming a large W at the anal angle of the hind wings. Nearer the margin of the hind wings beneath is an orange band. Like most of the other species of the genus, this Butterfly may be looked for in woods, and its larva feeds on the elm. The Green Hair-streak (*T. rubi*) is a commoner insect, found in open woods and heaths in spring and early summer, flying about, and settling upon brambles. It differs from the other European Hair-streaks by wanting the tail on the hind wings, and by the bright green colour of the under surface. On the upper side it is uniform brown. There are several South American species allied to this, which are blue above. The South American Butterflies of this genus present a great variety of colour and pattern on the under surface, but eye-spots, which are almost universal in *Polyommatus*, are seldom to be met with in *Thecla.* Some species resemble *Satyrinæ*, being streaked below in such a manner as to resemble Butterflies of the genus *Euptychia.* Some of the largest species expand about two inches across the wings, and are most beautifully coloured on the under surface. Several of these have two tails to the hind wings, and are gorgeously spangled with golden green beneath, and are sometimes varied with reddish or purplish markings. *Thecla marsyas*, on the other hand, is of a greenish-blue above, with the costa and tip of the fore wings black, and the under surface is very pale shining violet-grey, marked with black spots bordered with white.

THE GREEN HAIR-STREAK.

The species of *Thecla* have only ten nervures on the fore wings, but those of the next genus (*Zephyrus*) have eleven, the subcostal nervure emitting two branches before the extremity of the discoidal cell, and a third, which bifurcates, beyond. In *Thecla*, three simple nervures are emitted before the end of the cell, and none beyond. The *Zephyri* are not numerous, and are all found in Europe or Asia, except one species, which is Californian. The Purple Hair-Streak (*Z. quercus*) is common in oak woods. The male is purplish-blue, with black hind margins, and the female is brown, with a rich purple blotch on the fore wings. The under side is silvery grey, with a white line towards the hind margin, and some orange and black spots towards the hinder angles of all the wings. Several of the Japanese and North Indian species of *Zephyrus* are of a beautiful brassy green on the upper side.

Most of the remaining genera of the *Lycænidæ* are found in Asia or Africa, and are blue, brown, or white above, and adorned with one or two tails on each hind wing. These are generally very delicate and easily broken off, and are sometimes of very great length, equalling or exceeding the total length of the wings themselves.

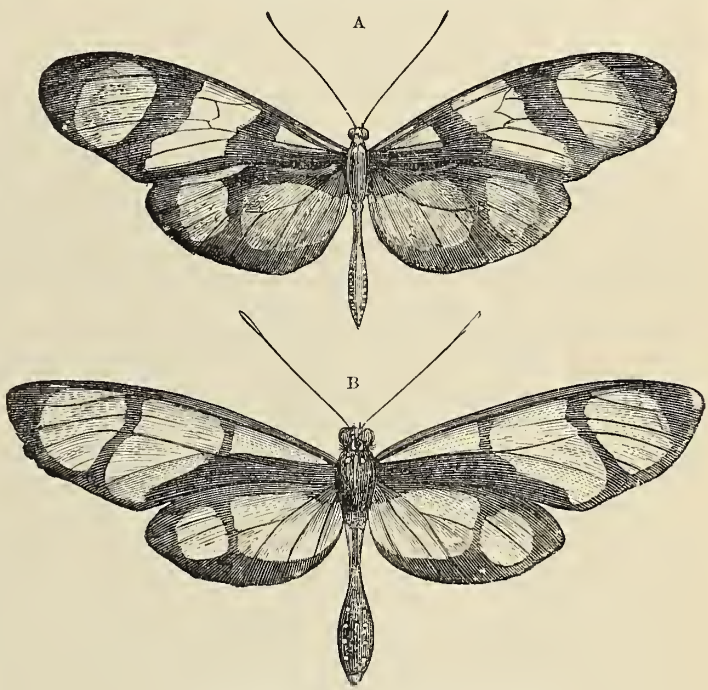
One of the commonest genera in the Eastern Archipelago is *Amblypodiæ*. These are blue Butterflies, often with brown borders, resembling our European species of *Thecla* in shape, and, like them, generally with a short tail on the hind wings. But they are much larger, many of the species measuring two inches across the wings. The under surface is brown, with darker bands and markings, bordered with pale lines.

Finally, *Eumæus* is a small South American genus, containing a few dark brown Butterflies, more or less marked with green on the upper side. The hind wings are bordered by a green band, and on the under side by three nearly contiguous rows of spots of the same colour.

FAMILY IV.—PAPILIONIDÆ.

The *Papilionidæ* may be at once distinguished from all other Butterflies (except the *Hesperiidæ*, which we need not now consider) by their possessing six perfectly-developed legs in both sexes. The pupa, or chrysalis, is not only attached by the tail, but is generally fixed in an upright position by a belt of silk round the body. There are two sub-families. In the first (the *Pierinæ*) the inner margin of the hind wings is not concave, and the larvæ are slender, and covered with fine hair. In the second sub-family (the *Papilioninæ*) the inner margin of the hind wings is concave, and the larvæ have always a retractile fork on the neck.

The *Pierinæ*, to which many of our commonest Butterflies belong, are, with few exceptions, white or yellow, with black spots and borders. They are Butterflies of about the middle size, seldom measuring less than an inch and a half, or more than three inches across the wings, and the wings are very rarely dentated, and though furnished occasionally with angular projections in the middle, or towards the anal angle of the hind wings, are never tailed, in the strict sense of the term.



A, DISMORPHIA ORISE; B, METHONA PSIDII.

The more aberrant genera are South American, and sometimes resemble other Butterflies, but the first (*Pereute*) stands quite by itself. These are black Butterflies, measuring nearly three inches across the rather broad wings, and most species have a transverse red bar across the fore wings. Many of the species of *Archonias* resemble some of the smaller *Nymphalidæ*, being black or brown, with a yellow or white band, often broken into spots, running across the middle of both pairs of wings. The hind wings are often more or less dentated, and are frequently ornamented beneath with numerous yellow spots and festooned markings of brown, black, and white.

The genus *Dismorphiæ* is likewise South American. It includes a number of long-winged Butterflies with narrow wings, which have no resemblance to the family to which they belong, but "mimic" various species of *Danainæ*. Many are black and yellow, others are marked with red, and some are even transparent, with black bands and borders. Most species can readily be distinguished from the Butterflies which they resemble by their very broad hind wings, but in some instances they are so much like the long-winged *Danainæ* that they might readily be passed over for them, but for the structure of their legs.

Most of the small white and yellow Butterflies of the Tropics belong to the genus *Eurema*. Many of them measure an inch, or under, across the wings, and few expand as much as two inches. They are never spotted, but the wings are more or less broadly bordered with black; and in some of the larger South American species the hind wings project below in an acute angle.

The genus *Pieris* includes the White Cabbage Butterflies, which are too well known to need description. Their green caterpillars may often be seen feeding on cabbage, &c., and the pupæ are found on walls and palings, and are not unfrequently surrounded by the little yellow cocoons of an Ichneumon Fly (*Pimpla manifestator*). The foreign species of *Pieris*, though numerous, call for no special notice, but the East Indian species, belonging to the allied genera *Tachyris* and *Delias*, are often very beautiful. *Tasbyris nero* has rather pointed fore wings, and is of a uniform red, with black nervures. On the under surface it is yellowish. Other allied species are blue, and others white, with brown borders. Most of the species of *Delias* are white, with a row of red spots along the borders of the hind wings beneath, and another East Indian genus (*Prioneris*) is remarkable for the costa of the fore wings being ridged like a saw in the males. *Perrhybris*, the last of the sections of the old genus *Pieris* which we need notice here, is found in South America, and is remarkable for the difference between the sexes. The male of *Perrhybris pyrrha* is white, with black borders above, but on the under side it is banded with white, black, and red. The female is streaked with black, yellow, and fulvous, giving it very much the appearance of one of the *Heliconinæ*, or of those *Danainæ*, which most resemble them. This Butterfly is very common in America, but there are several other species of the genus which exhibit a similar disparity in the sexes to a greater or less extent. The collection of the late Mr. Hewitson, now in the British Museum, contains a very singular specimen of *P. pyrrha*. It is a male, in which the right-hand wing is coloured as in the female, with the exception of one or two white spaces.

Most of the larger yellow Butterflies of the Tropics belong to the genus *Catopsilia*. They generally measure about three inches across the wings, though some are larger or smaller. The fore wings have the costa arched, and the hind margin nearly straight, and the hind wings are rounded, very slightly dentated, and occasionally obtusely pointed at the anal angle of the hind wings. The antennæ are of moderate length, and of a black colour. A few species are dull white, irrorated with brown on the under surface, but the greater number are of some shade of yellow or orange. The under surface is generally irrorated with reddish, and there is often a reddish-brown ring (frequently double) surrounding a silvery-white spot.

One of our prettiest Butterflies is the Brimstone (*Gonepteryx rhamni*), which is common in woods in most parts of England almost throughout the year. The male is sulphur-yellow, and the female whitish-yellow, and there is a small orange spot in the middle of each wing. The antennæ are short, thick, and of a reddish colour, and the body is black, clothed with long white hair. The Butterfly hibernates, and appears very early in spring; the green caterpillar feeds on buckthorn. An allied species (*G. cleopatra*) is common in South Europe, in which the fore wings are orange in the male, and there are one or two species of *Gonepteryx* in tropical America which are remarkably similar to *G. rhamni*, but are double the size.

The Clouded Yellow Butterflies of the genus *Colias* are found in every quarter of the globe, but in the tropics are only to be met with in the mountains. They are most numerous in temperate climates, and are Butterflies of moderate size, averaging about an inch and a half in expanse. The wings are moderately broad and more or less rounded, and are always of an orange or yellow colour, with a black border varying in width, which is generally lined with yellow in the male, and spotted with yellow in the female. There is a black spot in the middle of each fore wing, and there is often a single or double silvery spot surrounded with darker on the under side of the hind wings, as in *Catopsilia*. The caterpillars feed on clover and other leguminous plants, and the Butterflies are commoner in some years than in others, and are most frequently met with in autumn. Our commonest species, the Clouded Yellow (*Colias edusa*), is of a bright orange-yellow, with black borders, and is swifter on the wing than almost any other species. It flies low, but with such rapidity that it is very difficult to run down, though when not alarmed it will often settle on a flower, when it is easily captured. Some of the foreign species allied to this have a pink or purple flush over the orange,

which is occasionally visible in very fine specimens of *C. edusa*. And this species, as well as all the other orange species of *Colias* known, has two varieties of the female, one orange, and another—much scarcer—of a whitish colour. The Pale Clouded Yellow (*C. hyale*) is of a pale yellow colour, with narrower borders, and is a much scarcer insect than *C. edusa* in England, though more abundant on the Continent.

The Orange Tip (*Euchloe cardamines*) is a very pretty spring Butterfly, found in woods and meadows in April and May. It is white, with a black spot at the end of the cell of the fore wings, which are likewise tipped with dusky, and there is a large orange blotch filling up the whole space between, in the male only. The under surface of the hind wings and of the tip of the fore wings is chequered with green and white. It is an insect of weak flight, and very easily captured, but it is fond of settling with its wings closed on the flowers of umbelliferous plants—as observed by Mr. T. W. Wood—and as the colour of the under surface of the Butterfly is very similar to that of the plant, it is reasonable to suppose that it often escapes observation in this manner. The caterpillars are green, with a white stripe on each side, and feed on various cruciferous plants. The pupa is pointed at both ends, and somewhat resembles a boat in shape.

THE ORANGE TIP BUTTERFLY.

Orange Tips, belonging to the nearly allied genus *Teracolus*, are common in Africa, but most of these have either a black band on the inner margin of the fore wings, or a black border, or black marginal spots on the hind wings, and are not mottled with white and green beneath. In some species, however, the orange blotch on the fore wings is replaced by the most beautiful violet. The species of *Hebomoia* are rare insects, found in the Moluccas. One species only (*H. glaucippe*) is also common in India. It measures upwards of four inches across the wings, which are of a slightly yellowish-white. The outer portion of the fore wings is triangularly black, filled up by a broad band of connected orange spots, indented outwardly by the black border, and marked with an irregular row of small black spots in the middle.

THE ORANGE TIP BUTTERFLY AT REST.

The *Papilioninæ* are in general much larger and handsomer Butterflies than the *Pierinæ*. They exhibit great varieties of form and colouring, and the hind wings are generally dentated, and often tailed. The caterpillars are of various shapes, but are usually rather stout, and sometimes thicker in the middle than at the extremities. They have always a retractile fork on the segment behind the head, which is believed to be serviceable in driving away Ichneumon Flies, or other enemies.

The genus *Parnassius* more resembles the *Pierinæ* than any other of this group. The Butterflies are all mountain insects, and are confined to Europe, Asia, and the west of North America. The

best known species (*Parnassius apollo*) is abundant in the Alps. It is white, thinly scaled towards the extremities of the wings, and the fore wings are marked with several black spots. On the hind wings are two large round red spots, whitish in the middle, and enclosed in black rings. Most of the other species of *Parnassius* closely resemble this; but *P. mnemosyne*, also an Alpine species, has no red spots, but only two black spots on the fore wings, and even these disappear in the Siberian *P. Stubbendorfii.* The few known caterpillars of this genus are black, with rows of red spots on the sides, and feed on different species of saxifrage.

PARNASSIUS APOLLO.

The genus *Teinopalpus* is distinguished from any other of the sub-family by the unusual length of its palpi. *T. imperialis* is one of the rarest and most beautiful of Himalayan Butterflies, and measures about five inches across the wings, which are black, dusted all over with velvety green, and banded with purple. The hind wings are very strongly dentated, with one long tail in the male, and three in the female.

The great genus *Papilio*, which includes the well-known Swallow-tail Butterflies, may be known from the other genera of the family by its longer antennæ and very short palpi. There are about 500 species known at present, but only four are European, and the genus attains its maximum of size, beauty, and variety in Africa and the Eastern Archipelago. It is in the latter region that the splendid Bird-winged Butterflies, belonging to the sub-genus *Ornithoptera*, may be found. All the species included in it are very large insects, with long fore wings, measuring from five to eight or nine inches across, and short, more or less dentated hind wings, which, however, are not tailed. The first group have velvety-black wings, with a broad green stripe running parallel to the costa, and a narrower bar running near the inner margin and curving up along the hind margin. The hind wings are green, with a row of round black spots, and the abdomen is golden-yellow. Such are the males. The females are large black Butterflies, with two rows of white spots on the fore wings, and a row of very large oval ones, marked with round black spots, near the border of the hind wings. In one species (*Ornithoptera urvilliana*), which has been brought from Duke of York Island, the ordinary green of the male is replaced by the richest blue; in another (*P. crœsus*) it has been changed for the most brilliant golden-orange. The latter species is confined to the two small islands of Batchian and Gilolo, in the Northern Moluccas, where it was discovered not many years ago by the enterprising traveller and naturalist, Mr. A. R. Wallace. After having only caught an occasional glimpse of this magnificent species flying far out of reach, he succeeded in finding a beautiful shrub with yellow flowers which was frequented by the insect; and subsequently his native collector met with it flying along the bed of a large rocky stream, and settling occasionally on stones and rocks in the water. Mr. Wallace thus describes his first capture of the insect:—"None but a naturalist can understand the intense excitement I experienced when I at length captured it. On taking it out of my net, and opening the glorious wings, my heart began to beat violently, the blood rushed to my head, and I felt much more like fainting than I have done when in apprehension of immediate death. I had a headache the rest of the day, so great was the excitement produced by what will appear to most people a very inadequate cause."*

The second group of *Ornithoptera* is not confined to the islands, but extends to India and South China. The fore wings are narrower than in the preceding group, and are black, while the hind wings are yellow or golden-yellow in the centre, with black borders, or conical marginal spots, and often a row of round black spots within them.

The third group contains but one species—another grand discovery of Mr. Wallace's—*Ornithoptera Brookeana*, from Borneo and Sumatra. It is black, with a row of large green spots on the outer portion of the fore wings. They are of a long triangular form, the apices extending to the margins.

* "Malay Archipelago," ch. xxiv

The hind wings have a broad continuous band of green across the centre. The collar is broadly red.

There is a very large and difficult group of South American *Papilios*, resembling *Ornithopteræ* in form, but less than half the size, only averaging about three inches across the wings, which are black, often with a large white or green spot on the fore wings, and with a crimson band on the hind wings, which is not unfrequently glossed over with the most beautiful pale iridescent bluish or greenish violet. Another South American group resembling these has a short pointed tail on the

LEPTOCIRCUS CURIUS. ORNITHOPTERA AMPHRISUS.

hind wings; and a third group from the same country includes brown species of larger size, with one or two rows of ochreous yellow spots running round all the wings. The hind wings are dentated but not tailed.

Among the East Indian species there are some brown Butterflies, glossed with blue and spotted with white in the same manner as in the genus *Euplœa*, which they resemble in shape and size as well as colour. A second East Indian group is black, with a large white spot, divided by the veins on the hind wings, which are tailed; and a third section, closely resembling this, contains black species, dusted all over with golden-green. Both these groups contain species of considerable size, often measuring four inches or more across the wings. These lead us on to the splendid *Papilio ulysses* and its allies, which are met with, like the *Ornithopteræ*, in the Eastern Islands. These are large blue Butterflies, with black borders, and tails on the hind wings. Mr. Wallace describes one species as darting down in openings of the forest from the tops of the trees for a moment, and

then soaring out of sight with equal suddenness. All these large Butterflies appear to have a very lofty and powerful flight, and the difficulty of obtaining them is frequently the chief cause of their rarity in collections.

The commonest of the European Swallow-tails, and the only one found in England, is *Papilio machaon*. It is a sulphur-yellow Butterfly, with black markings, and borders to the fore wings. The hind wings are tailed, and their dark border encloses a row of large bluish spots, and there is a large red spot at the anal angle. The caterpillar is green, with black stripes spotted with orange on the sides, and feeds on various umbelliferous plants, including the common carrot. In England this Butterfly is confined to the fenny districts in the east, but on the Continent it is quite a common species in gardens, clover-fields, and woods.

PAPILIO MEROPE.

Many East Indian or African species are black, spotted or banded with green, and several of the latter feed on the orange-tree; but a far more remarkable African Butterfly is *P. merope*. The male is a cream-coloured Butterfly, with black borders to the fore wings, marked with a pale spot near the tip. The hind wings are tailed, and marked with a more or less connected row of black spots; but the females are all tailless, and have no resemblance whatever to the male in either shape or colour, but resemble various African species of *Danainæ*. One female is black, with ochreous spots and markings; another is black, with a very broad white band across the hind wings (sometimes extending nearly to the base), and continued on the inner margin of the fore wings. There is also a broad white transverse band towards the tip of the fore wings, and several smaller white spots. Another female is similar to this, but the pale markings are deep ochreous-yellow, the hind wings being wholly of this colour, except a black border. In others, again, the fore wings are black and white, and the hind wings are of some shade of yellow, with black borders. Other species of *Papilio* are known in which the females differ equally from the males, or which are polymorphic; but this Butterfly is peculiarly remarkable, because a closely allied species occurs in Madagascar, in which the female only differs from the male by the presence of a broad black bar on the costa of the fore wings.

The genus *Leptocircus* includes a few small black, green, and transparent East Indian Butterflies, of a very peculiar shape, which will be seen in the figure on p. 51.

FAMILY V.—HESPERIIDÆ.

The *Hesperiidæ*, the last family of Butterflies, although numbering at least 1,500 species, need not detain us long, as very few are found in Europe, and the foreign species call for but little remark. They are mostly small Butterflies, with thick bodies and comparatively small wings. The six legs are all fully developed in both sexes, and the head is large. The antennæ, instead of being placed close together, as in other Butterflies, are placed widely apart, and are often hooked at the tip. The caterpillars are short, tapering at both ends, and the head is large. They generally live between leaves loosely spun together, and construct a slight cocoon in the same manner. The Butterflies are called Skippers, from their short jerking flight.

The first genus (*Thymele*) is confined to tropical America, and may be known by the hind wings being produced into a rather long, broad tail. The Butterflies are brown, often greenish towards the

base, and with transparent dots or spots on the fore wings. *Telegonus* is another American genus, containing rather larger species, with a lobe instead of a tail at the anal angle of the hind wings. These are brown Butterflies, with yellowish-tawny markings. *Casyapa* is an East Indian genus, also brown, with large yellowish spots on the fore wings, but the hind wings are not produced at the anal angle. These Butterflies are among the largest of the family, measuring three inches in expanse, but they are surpassed by the African *Ismene iphis*, the giant of the *Hesperiidæ*, which sometimes measures as much as four inches across the wings. This is a black or bronzy-greenish Butterfly, with rather long fore wings and long hind wings, lobed at the anal angle; the collar and part of the head are scarlet. Other species of *Ismene*, usually of rich dark colours, but much smaller than *I. iphis*, are common in Asia and Africa. The genus *Pyrrhopyga* is South American, and includes several black or blue-black species, generally with a red head and tail, and sometimes with reddish or yellowish borders. The hind wings are often slightly produced at the anal angle. They generally expand rather less than two inches, but some of the larger species are black, with their bodies striped and banded with black and white, or black and green, and their wings marked with transverse bands, some green and some transparent.

A, AMAURIS NIAVIUS; B, PAPILIO MEROPE (FEMALE).

The great genus *Pamphila*, the most typical of the family, contains small species, seldom exceeding an inch and a half in expanse. Most of the species are brown, with tawny markings, and there is nearly always a black longitudinal patch of raised scales on the fore wings of the male. In many species, as in the Pearl Skipper (*P. comma*), a common Butterfly on the chalk in the South of England, the hind wings are green beneath, with white spots. The species of *Hesperia* are small Butterflies resembling our own Grizzled Skipper (*H. malvæ*), which is common in woods in spring. It is blackish-brown, with many white spots, which form irregular bands on the fore wings, and the fringes are also spotted with black and white. Several allied species are found on the Continent.

The South American genus *Pythonides* is allied to this, and contains species of about the same size. Some of these are white, with dark borders and dark veins; others are dark brown, with bluish or transparent spots on the fore wings, and a blue band or border on the hind wings. Our Dingy Skipper (*Nisoniades tages*) is a dull brown Butterfly, with very obscure markings, and several of the foreign genera are also very obscurely marked. The South American *Achlyodes busirus* is a blackish Butterfly with obscure darker markings and a rather irregular outline. The hind wings are bordered with yellowish beneath.

At the end of the *Hesperiidæ* we may place a few species of doubtful position, intermediate between Butterflies and Moths. One of these (*Megathymus yuccæ*) is a rather long-winged insect, expanding nearly three inches. It is brown, with tawny markings, and is found in the Southern

United States and Mexico, where its caterpillar lives in the stems of the American aloe. Another species (*Euschemon Rafflesiæ*) is an Australian insect of nearly equal size. It is of a rich velvety black, with bright yellow markings on the hind wings, and is remarkable for having the fore and hind wings connected by a bristle at the base, an arrangement frequently met with in Moths, but not occurring in any other known Butterfly.

CHAPTER XI.

MOTHS.

The Pages—The *Castniidæ*—Moths with Clubbed Antennæ—Humming Bird Hawk Moth—Bee Clear-wings—Lovers of the Vine—Eyed Hawk Moth—Death's Head Hawk Moth—Scented Hawk Moths—Hornet Clear-wing—Currant Clear-wing—The Green Foresters—The Burnets—Day-flying Moths of the East Indies—The Footmen—The Tigers—The Gold-tail Moth—The Gipsy Moth—Case-bearing Moths—The Puss Moth—The Prominents—The Lobster Moth—The Processionary Caterpillars—The Silkworm—The Atlas Moth—The Ailanthus Silkworm—The Tusseh Silkworm—Long-tailed Moths—The Emperor Moth—The Lappet Moth—The Oak Eggar—The Lackey Moth—The Wood Leopard Moth—The Goat Moth—The Swifts—The Night Moths—The Wainscots—The Dark Arches—The Cabbage Moth—The Cut-worms—The Yellow Underwings—The Chestnuts—The Angle Shades—The Sharks—Beautiful Yellow Underwing—The Gamma Moth, or Silver Y—The Burnished Brass Moth—The Old Lady—The Red Underwings—The Orange Moths of Australia—The Great Owl Moth—The Snout—The Loopers—The Swallow-tail Moth—The Brimstone Moth—The Thorns—The Emeralds—The Waves—Heath Moths—The Soldier Moths—The Magpie Moth—Winter Moths—The Pugs—The Carpets—*Erateina*—The Pearls—The Meal Moth—The Crimson and Gold—The China Marks—The Small Magpie—The Knot-horns—Their Webs—The Grass Moths—The Bell Moths—The Green Oak Moth—Pests of the Orchard—Jumping Seeds—Clothes Moths—Long-horns—The Smallest Moth known—The Plume Moths—The Twenty-plume Moth—Fossil Butterflies and Moths.

Moths are many times more numerous than Butterflies. In Britain we have about thirty Moths to every Butterfly; and although the same proportion does not hold good elsewhere (for there are only seventeen Moths to one Butterfly on the Continent), yet, taking the whole world, we are at present acquainted with about 40,000 or 50,000 Moths, and only 10,000 or 12,000 Butterflies, although comparatively little attention has yet been bestowed on Moths either by collectors or entomologists. In discussing the Moths, therefore, we must here content ourselves with briefly noticing the principal families, and a few of the more interesting species. But the classification of Moths is at present much less satisfactory than that of Butterflies, and it is not pretended that the families of Moths about to be enumerated follow in natural order. But we find throughout nature that many groups of animals and plants combine the characters of others in varying proportions, and that it is frequently impossible to arrange either families, genera, or species in a linear series which is also natural, even in the case of groups which are much better understood than the Moths. The old groups, *Sphinges* and *Bombyces*, the first of which included the families up to the *Zygænidæ* inclusive, and the latter the remaining families to the *Hepialidæ* inclusive, are now abandoned by most entomologists as scientifically accurate terms, though still frequently used for convenience in a general manner.

The *Uraniidæ*, or Pages, include a small number of very beautiful Moths, formerly regarded as Butterflies, and still of doubtful position. The typical genus *Urania* is South American. The species are all transversely banded with black and green, and there is a long tail, sometimes edged with white, on the hind wings. They measure about three inches across the wings, and but for the long and slender antennæ might well pass for true *Papilios.* They fly by day, and one species (*Urania fulgens*) migrates in large flocks at certain seasons across the Isthmus of Panama. Several genera allied to this, but of duller colours, are found in the East Indies, but one of the most beautiful insects known is the splendid *Chrysiridia madagascariensis,* which is banded with black and green. The hind wings are three-tailed, and a great part of their surface is of a flame-coloured red, shading into orange on the under surface, and with black markings. This insect, which measures four inches across the wings, is common in Madagascar and at Zanzibar; and it is stated that if the Moth emerges from the chrysalis in the shade the wings take much longer to develop, and are much less brilliant than when it emerges in the sunshine. These Moths are referred by some writers to the *Geometridæ.*

The *Castniidæ* are another group of day-flying Moths, common in the East Indies and America, which used to be regarded as Butterflies by early writers on entomology. They have robust bodies,

and broad wings; the antennæ are stout, and thickened gradually before the extremity, which ends in a slender hook. The South American species of *Castnia* are large Moths, measuring from two to six inches across the wings, and in many cases the fore wings are dark, and the hind wings banded with white, and spotted towards the borders with red. But they vary considerably, both in form and colour. Some few species of the family are transparent; and in the Australian genus *Synemon* the antennæ are clubbed, and the Moths, which expand about an inch and a half across the wings, might easily be mistaken for *Hesperiidæ*.

THE HUMMING BIRD HAWK MOTH.

We now come to the great family of *Sphingidæ*, or Hawk Moths, which may be known by their large head, prominent eyes, stout antennæ, more or less thickened in the middle, and often serrated, but not pectinated, in the males, and their long, narrow, pointed wings. The caterpillars are smooth, often green, with transverse stripes on the sides, and there is nearly always a horn on the back of the last segment but one. They change to pupæ either on the surface of the ground or in a cell under ground, which they form for the purpose. Every one is familiar with the Humming Bird Hawk Moth (*Macroglossa stellatarum*), which may often be seen buzzing over the flowers in our gardens, and rifling them of their sweets by means of its long proboscis, without ever resting. It is not uncommonly mistaken for a real Humming Bird, and some of the allied South American species actually resemble Humming Birds so closely in flight that they cannot be distinguished from them on the wing; and during his travels on the Amazons Mr. Bates often shot one of these Moths by mistake for a Humming Bird. Our common species has brown fore wings, and reddish tawny hind wings, and the abdomen is tufted at the extremity. Most of the foreign species are very similarly coloured.

THE OLEANDER HAWK MOTH. (*Chærocampa nerii.*)

The Bee Hawk Moths (*Sesia fuciformis* and *bombyliformis*) are of about the same size and shape as the Humming Bird Hawk Moth; but their bodies are yellow, with a reddish-brown belt, and downy, and the wings are transparent, with brown or reddish-brown borders. They are not uncommonly seen flying over flowers in woods in spring, but their flight is much less rapid than that of *M. stellatarum*. There is a beautiful Continental Hawk Moth about the same size as

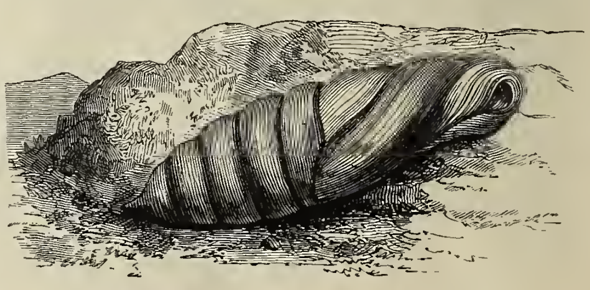
these, with green fore wings and yellow hind wings, and the borders of all the wings are strongly dentated. It is called *Pterogon proserpina*, and flies at dusk.

Many of the larger *Sphinges* feed on the vine, the best known of which is the Sharp-winged Hawk Moth (*Chœrocampa celerio*), which is common in many parts of Europe, Asia, and Africa, though rare in Britain. It has pale brown fore wings, with a waved silvery stripe running from near the base of the inner margin to the tip; the hind wings are rose-colour, with the hind margins and a central streak broadly black. The caterpillars of the genus to which this insect belongs have the front segments tapering and retractile, which gives them a fancied resemblance to a hog's snout or elephant's trunk, whence they derive their Greek name of *Chœrocampa* (hog's snout), and their English name of Elephant Hawk Moths, generally applied to two smaller and commoner species of this genus. There is an American genus allied to these, called *Philampelus* (or vine-loving), because most of the species feed on this plant. One of the most singular species is *Philampelus labruscœ* (the lover of the wild vine), which is common in Central and South America. The fore wings are dull green, and the hind wings are pale blue and black at the base, with broad pale yellow borders. It measures about five inches across the wings.

THE EYED HAWK MOTH.

Our only genus of Hawk Moths with dentated wings is *Smerinthus*, to which the Eyed Hawk Moth (*S. ocellatus*) belongs. The fore wings are light brown, and the hind wings are pale pink, with a large round blue spot in a black ring towards the anal angle. One of the allied North American species (*S. geminatus*) has a double eye in a similar position.

One of the most remarkable species of this group is the Death's Head Hawk Moth (*Acherontia atropos*), the largest Moth found in Britain. The fore wings are dark brown, varied with black, grey, and yellowish, and the hind wings are dark yellow, with two black bands. On the back of the thorax is a pattern in grey and black, not unlike a skull. The abdomen is banded with black and yellow, with a longitudinal bluish-grey band on the back. The body is very stout, the antennæ are thick and rather short, and the wings expand about six inches. The enormous yellowish-green caterpillar, with dark stripes on the sides, feeds on various plants, including the potato, and has actually been sometimes mistaken for the Colorado Potato Beetle! The Moth is capable of producing a sound resembling the squeaking of a mouse, and will sometimes enter hives to feast on the honey. It is supposed that its squeak overawes the Bees, in the same manner as the voice of their own queen. I may here mention that I once knew a German artisan who was an enthusiastic collector of Butterflies and Moths, and when he was dying he requested a friend to place a specimen of this insect on his breast in his coffin, which was accordingly done.



CHRYSALIS OF DEATH'S HEAD HAWK MOTH.

The type of the *Sphingidœ* is the Privet Hawk Moth (*Sphinx ligustri*). It measures about four

inches across the wings, which are pale brown, varied with darker brown and black ; the hind wings are pale pink, crossed by three black bands. The green caterpillar, with white and lilac streaks on the sides, and a black horn on the back, feeds on privet and lilac, and the position which it assumes when at rest suggested that of the mythological Sphinx to the old naturalists, who applied this name to the insect.

CATERPILLAR OF DEATH'S HEAD HAWK MOTH.

The small family of the *Ægeriidæ*, or Clear-wings, contains a few Moths with transparent wings, the caterpillars of which feed in the stems of trees or plants. In the first genus (*Sphecia*) the body is stout, and not tufted; *S. apiformis*, which may often be found sitting on the trunks of poplars in early summer, looks very much like a large Wasp, being black and yellow, and of about the same size. Another species (*S. bembeciformis*) feeds on osiers. The species of the other genus (*Trochilium*) are much smaller insects, with long slender bodies, tufted at the extremity. The commonest species, the Currant Clear-wing (*T. tipuliformis*), which measures about three-quarters of an inch across the wings, has transparent wings, with black borders slightly varied with orange, three yellowish rings on the abdomen, and a black tuft at the extremity. It is common and sometimes injurious in gardens, where its caterpillars live in the shoots of the currant, but the Moth is very liable to be mistaken for some kind of fly.

THE DEATH'S HEAD HAWK MOTH.

The family *Zygænidæ* contains the Green Foresters and the Burnets. The former have thick and obtuse, or slender, antennæ, sometimes slightly pectinated; in the Burnets the antennæ are strongly thickened before the tip. They are all small insects, with rather long fore wings and shorter hind wings, and rather stout bodies; they fly heavily and gregariously in meadows or waste places by day. The Green Foresters (*Ino*) have green fore wings and brown hind wings; the Burnets (*Zygæna*)

have steel-blue or greenish fore wings, spotted or streaked with bright red, and the hind wings are of the same colour, which, however, is occasionally liable to be replaced by yellow, as an accidental variation. The yellowish cocoon is often met with attached to the stems of grass, &c. Many of the East Indian species of this family have transparent spots on the fore wings, and some of the South American species are completely transparent.

SPHECIA BEMBECIFORMIS.

The family *Chalcosiidæ* is allied to the last, but the species are larger and adorned with very bright colours. They fly by day, and some species resemble *Papilio* in shape and colour, while others might be mistaken for *Eupœla*. The antennæ, however, are generally simple, and are always unmistakably those of a Moth. These species are East Indian.

The *Lithosiidæ*, or Footmen, are a group of Moths with simple antennæ, rather narrow fore wings, and broad hind wings, which are folded beneath when at rest. In the net they usually simulate death. The fore wings are generally grey, with the costa yellow, and the hind wings pale yellowish. The Moths expand about an inch and a quarter, and some species are marked with a few black dots.

ZYGÆNA FILIPENDULÆ.

The *Arctiidæ*, or Tiger Moths, are the most beautiful family of Moths found in Europe. The common Tiger Moth may be taken as typical of the group. It measures from two to three inches across the wings, which are black, with interlacing white markings; the hind wings are red, with large black spots bordered with yellowish. The abdomen is also red, with black markings. The caterpillar is often called "the Woolly Bear," being covered with tufts of long hair, which is black, tipped with white on the back, and reddish-brown on segments 2-4 and on the sides. When disturbed, it rolls itself up into a ball.

COCOON OF ZYGÆNA FILIPENDULÆ.

Most of the other species of this family are similarly coloured, having dark fore wings, with white or yellow markings, and red or yellow hind wings, with round black spots. But some species are less gaudily coloured, and the White and Buff Ermines (*Spilosoma menthastri* and *lubricipeda*), which are common in gardens, are white or yellowish, with black dots.

Many of the *Liparidæ* are white Moths, more or less marked with black. The bodies of the females are thick and tufted at the extremity. This tuft is very conspicuous in the Gold-tail and Brown-tail Moths (*Porthesia chrysorrhœa*, and *auriflua*). They are white, with or without a black spot near the anal angle of the fore wings, and measure about an inch and a half in expanse. The eggs are laid in a cluster, and covered by the female with down plucked from the tuft with which she is provided for the purpose. The Moths are common on hedges on summer evenings.

The male of the Vapourer Moth (*Orgyia antiqua*) is about the same size, but has broader and shorter wings. It is orange-brown, with a white spot near the hinder angle of the fore wings, and is a most abundant insect, flying everywhere, about bushes, and even in the streets of London, where there are trees in squares or gardens within any reasonable distance. The female has rudimentary wings, and looks something like a spider. The Gipsy Moth is a larger insect, very abundant and destructive on the Continent, but rare in Britain. The male, which expands rather more than an inch and a half, has a slender body and broad wings. The female is white, with a thick body and longer wings, and is very much larger than the male. She is generally found resting on hedges or tree trunks in the day-time, while the male flies rapidly by day, like that of *Orgyia antiqua*. In most of the *Liparidæ* the antennæ are strongly pectinated in the males, and are more simple in the females.

PSYCHE MUXELLA.

The *Psychidæ* are a family of small Moths, in which the males expand an inch or less, and have uniform blackish or whitish wings, rounded at the extremities. They fly in grassy places by day, and the caterpillars construct movable cases of bits of grass, leaves, &c., not unlike those formed by the larvæ of Caddis Flies. In these they change into pupæ, and the females of some species never leave them, for the females of all the species are apterous, and in some genera the legs and antennæ are undeveloped too.

The *Notodontidæ* are a family of larger Moths, measuring from half an inch to two inches and a half across the wings, which are rather long, and rounded at the extremity. Many of them are called "Prominents," from a projection on the inner margin of the fore wings. The Moths are generally of dull colours—white or brown, with darker markings, or tawny, with dark lines or white spots on the costa. But the caterpillars are far more interesting from their strange shapes and habits. The first which we shall mention is the Puss Moth, a common insect, of which the caterpillar feeds on poplar and willow. The Moth measures nearly three inches across the wings, which are white, suffused with greyish, with zigzag blackish transverse lines. The thorax and abdomen are spotted with black. The caterpillar is green, with a large retractile head bordered with red, and a dark mark on the back, varied with greyish-brown or red, and bordered with white. This mark is very broad in the middle (where it is somewhat greenish), and then tapers off towards the tail. The caterpillar has only fourteen legs, the claspers being replaced by two long, slender tubes, from which soft threads can be protruded. This large, green, hump-backed caterpillar, with its forked tail, can hardly be mistaken for any other. There are three species of the same genus found in Britain, which are sometimes called "Kittens" by collectors, but they are much smaller as well as much rarer.

PUSS CATERPILLAR AND MALE MOTH.

One of the prettiest Moths of this family is *Microdonta bicolera*, which is snow-white, with orange spots on the fore wings, and expands about an inch and a half. It is a great rarity in England.

The Lobster Moth (*Stauropus fagi*) is also rather a scarce insect, though much commoner than the last. It is of a brownish-grey, with darker markings, and expands about two inches and a half. The caterpillar is chestnut-brown, with enormously long legs and two projections at the extremity of the body. It feeds on a great variety of trees, and when at rest it stands on its prolegs, and lifts up both extremities of its body, giving it, as may well be supposed from its long front legs, and its two anal appendages, a very odd appearance, which has given the Moth its English name.

The Processionary Moth (*Cnethocampa processionea*) is an obscure, yellowish-grey insect, with darker markings, and expands rather more than an inch. It is only doubtfully British, but is frequently met with on the Continent, where the caterpillars, which are bluish-black on the back and whitish on the sides, feed gregariously on oaks. They form large webs, and go out to feed in regular order, first one, then two, then three, &c. They are covered with fine barbed hairs, and these, as well as the dust in the webs, are so terribly irritating to the skin, that it is scarcely safe to approach the nests; and it is even said that death has sometimes been caused by the swelling and inflammation thus produced.

Another larger species feeds on fir-trees, and is not found so far north as the last (*P. pityocampa*).

The hairs of the caterpillars are just as irritating as those of *C. processionea*, or even more so. These caterpillars march in single file, instead of in an increasing series. The great enemy of both species is a large green Beetle, called *Calosoma sycophanta*.

The only European species of the small family of the *Bombycidæ* is the Mulberry Silkworm (*Bombyx mori*). The caterpillar is creamy white and naked, with a hump on the last segment but one. Its real food is the white mulberry, but in England it is often fed on lettuce. The Moth measures about two inches, or rather less, across the wings, which are somewhat falcate, and are of a yellowish-white colour, with indistinct dusky transverse lines. The cocoon is yellow or white, according to the breed, and it is from this that the greater part of the silk used in commerce is obtained. The Silkworm was originally a native of China, and Chinese historians attribute the discovery of the use of silk to the Queen of the Emperor Hwáng-té, who lived about 2640 B.C., and the rearing of Silkworms formed one of the principal duties of the queens and ladies of the court for many centuries afterwards. A great deal of silk is also reared in those parts of India where the climate is sufficiently favourable to the growth of the insect. The Silkworm was first introduced into Europe in the reign of Justinian by some missionaries, who smuggled the eggs to Constantinople concealed in canes. The rearing of Silkworms soon became common, and has ever since formed one of the staple industries of Southern Europe, where the insect has become naturalised in many places. The caterpillar is, however, subject to many diseases, which have greatly diminished the yield of silk of late years. The Moth is not reared in England, except as a curiosity, although it is perfectly able to bear the climate. I am informed that English-grown silk is of very good quality, but that the thread is too short to be of any commercial value. The domesticated Moth is a heavy insect, quite incapable of flight, but if reared in perfect freedom in the open air it recovers the power in a few generations.

THE LOBSTER CATERPILLAR AND MOTH.

Although *Bombyx mori* is the only Moth reared for its silk in Europe, several other species belonging to other families are used for the same purpose in China, India, and Japan. Most of these belong to the *Saturniidæ*, a family which includes many of the largest Moths known, nearly all of which have either a large transparent spot, or a large round eye-spot in the middle of each wing. The antennæ are strongly pectinated, especially in the males, and the body is stout, and often very short. The Atlas Moth (*Attacus atlas*) sometimes measures nearly a foot across the expanded wings, which are of a tawny fawn-colour, with a large triangular transparent spot on each. The Ailanthus Silkworm (*Attacus cynthia*) belongs to the same genus, but is a much smaller insect, only measuring about five or six inches across the wings. The Moth is of a dull olive-green, with a large transparent lunule, edged below with yellow, on each wing. There is also a broad suffused pink band, edged within

with white and then black, running across all the wings. The caterpillar is yellow, greyish-blue, or green, according to age, and spotted with black. When half-grown it becomes studded with long white tubercles, which secrete a waxy powder. It forms a cocoon resembling brown paper, folded in a leaf of the tree, which is connected with the branch by a silk riband, so that there is no danger of the cocoon falling from the tree when the leaf dies. This insect, which is a native of China, feeds on *Ailanthus glandulosa,* a naturalised tree, is very easily reared, and has been introduced into England, and many parts of the Continent, and has become wild in some places. But as there are great difficulties in successfully winding the silk, speculators have rarely attempted to rear it on a sufficiently large scale to test its actual value as an article of commerce.

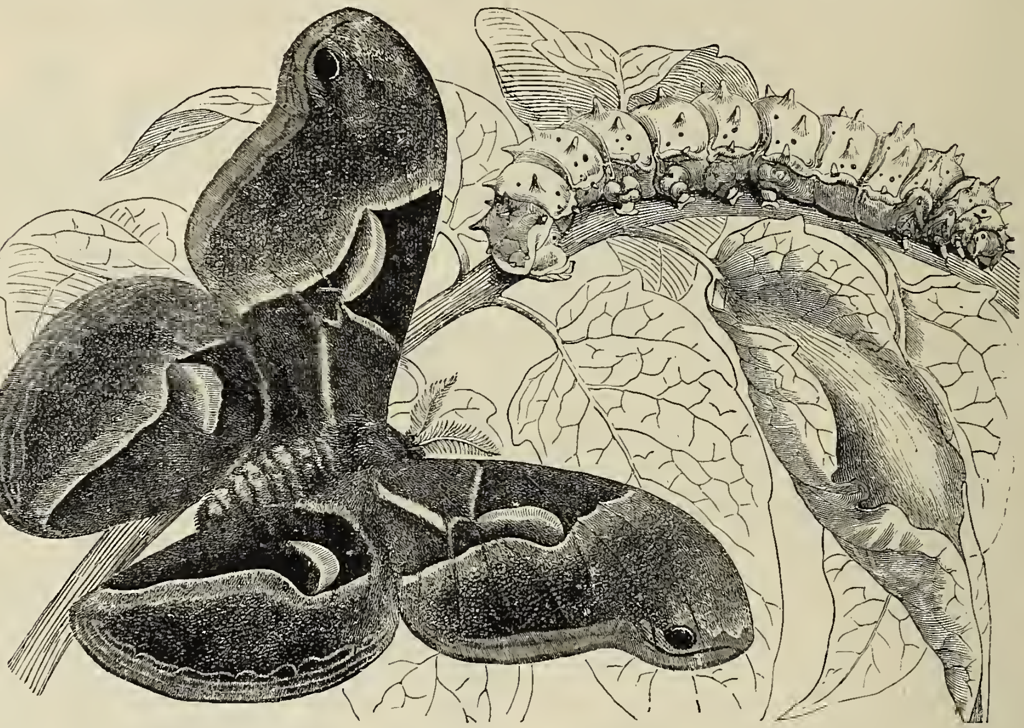
A great deal of the silk which is used in Japan is produced by the Oak-feeding Silkworm (*Antheræa yamamai*), which yields a large and beautiful green cocoon of excellent quality. The Moth is a large yellow insect, measuring about seven inches across the wings, which are narrower than in the genus *Attacus.* In the middle of each wing is a round transparent spot. The Japanese Government long reserved the monopoly of this insect to Japan, its exportation being prohibited on pain of death. But notwithstanding this, eggs were smuggled out of the country from time to time, and there is now no restriction on their exportation. Nevertheless, Europe has not yet profited by the introduction of the insect, for although great hopes were based upon it, it is very difficult to rear, and rapidly degenerates in Europe. The cause of its failure has not yet been discovered. Several other closely-allied species are used for the production of silk. Among these is *Antheræa pernyi,* a Silkworm which feeds on the oak in North China; and *Antheræa mylitta,* the Tusseh Silkworm, a common Indian insect, which yields a rather coarse-looking silk, which requires to be carded, for it cannot be wound, but which is so durable that a dress made of it frequently descends from mother to daughter, as it takes more than one lifetime to wear it out.

CATERPILLAR, COCOON, AND MOTH OF BOMBYX MORI.

Several of the Moths of this family have long tails on the hind wings. These are not mere projections, as in many Butterflies, but are more like prolongations of the wings themselves. In the genus *Actias* all the species are tailed, and are of a green or yellow colour, with an eye on each wing. They expand from three to six inches, and most of the species are found in the East Indies, though single species are met with in Spain, Natal, Madagascar, and North America. The genus *Eudæmonia* includes a few smaller insects, of a brown or yellow colour, found in Africa and South America; and although they do not measure more than about three inches across the wings, the tails alone are nearly six inches in length in some species.

The only British species belonging to the family *Saturniidæ* is the well-known Emperor Moth (*Saturnia carpini*). It measures between two and three inches across the wings, which are grey in the female, whereas the fore wings of the male are reddish-brown, and the hind wings rusty yellow.

There is a large black eye in the middle of each wing marked with a white crescent inside, and surrounded with yellow and black rings. The caterpillar is green, with black transverse bands and reddish tubercles, studded with short hair. It feeds on heath, &c., and constructs a hard pear-shaped cocoon. The Emperor Moth is not an uncommon insect, but it is allied to the Great Peacock Moth (*Saturnia pyri*), which measures six inches across the wings, and is the largest Moth found in



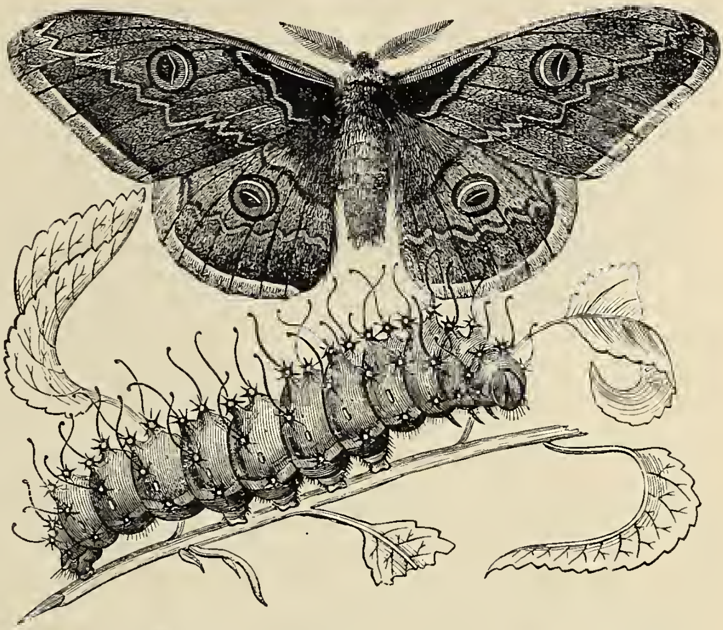
CATERPILLAR, CHRYSALIS, AND MOTH OF SATURNIA CYNTHIA.

Europe, but has not been met with farther north than Paris or Vienna. It is a dark grey Moth with white borders, within which the wings are much darker than elsewhere. The eyes resemble those of *S. carpini*, but are dusted with blue, and the caterpillar is green, with blue warts instead of red ones, and it feeds on different kinds of trees, especially fruit-trees.

The *Lasiocampidæ* are large or middle-sized Moths, with stout, hairy bodies, and strong wings, and the caterpillars are clothed with soft hair. The Moths are generally of dull colours—brown, reddish-brown, or yellowish predominating.

The Lappet Moth (*Gastropacha quercifolia*), which is not very common in England, may be known by its reddish-brown dentated wings, marked with zigzag transverse lines. The Oak Eggar (*Lasiocampa quercus*), which is of about the same size, is a much commoner insect, and the hind margins are not dentated. The male is chestnut-brown, and the female ochre-yellow; across the wings runs a broad transverse band of pale yellow, which is much more distinct in the male than in the female, but there is a white spot in both sexes about the middle of the fore wings. The caterpillar is black, with paler hairs, and a white stripe on each side. It feeds on many plants, including oak, and forms an egg-shaped cocoon, whence its name. The male flies very rapidly in the daytime, but may easily be decoyed within reach, if the collector has bred a female from the caterpillar, and carries her alive to a spot frequented by the males. It is not necessary to set her at liberty, or even to keep her in an open box; she will attract the males just as readily if carried in a closed box in the pocket. The Lackey Moth (*Clisiocampa neustria*) is a smaller representative of this family, only expanding about an inch and a half across the wings. The fore wings are either ochre-yellow, with two brown transverse stripes, or brownish-red, with pale yellow ones; the hind wings are paler than the fore wings, and unstriped. The caterpillars are striped with blue, red, and yellow, with a white

line on the back, and they live gregariously on trees under a common web. The Moth is very common in many parts of England, and the female lays her eggs closely glued together in a broad ring round a slender twig.



MOTH AND CATERPILLAR OF SATURNIA PYRI (TWO-THIRDS NATURAL SIZE).

The *Zenzeridæ* are rather large Moths, whose caterpillars feed on wood, inside the trunks of trees, often causing considerable damage. The Wood Leopard Moth (*Zeuzera æsculi*) appears to be commoner round London than elsewhere in England. It is white, with many steel-blue spots on the wings and thorax, and its caterpillar, which is yellow, with a black head, infests apple, ash, and other trees. The Moth measures two inches or more across the wings, and the abdomen is long, and furnished with an ovipositor in the female. The Goat Moth (*Xylentes cossus*) is a commoner insect. It is shaded with grey and brown, and marked with many irregular black transverse lines. It measures three inches or more across the wings, and is a very heavy-looking Moth, with a thick body, which scarcely extends beyond the hind wings. The caterpillar is dirty flesh-colour, with the back brownish-red. It lives in trees, especially poplars and willows, and is not full-grown until it is three years old. Some writers have supposed that this caterpillar was the *Cossus* which was considered a great dainty by the Romans; but it is much more probable that their *Cossus* was the larva of some large wood-feeding Beetle.

THE LACKEY MOTH AND CATERPILLAR.

The *Hepialidæ* are a small group with narrow rounded wings, very short antennæ, and very long bodies. The largest species is the Ghost Moth (*Hepialus humuli*), which measures about two inches across the wings. The male is white above and brown beneath, and the female has dull-yellow fore wings, with two oblique red stripes, more or less broken into spots,

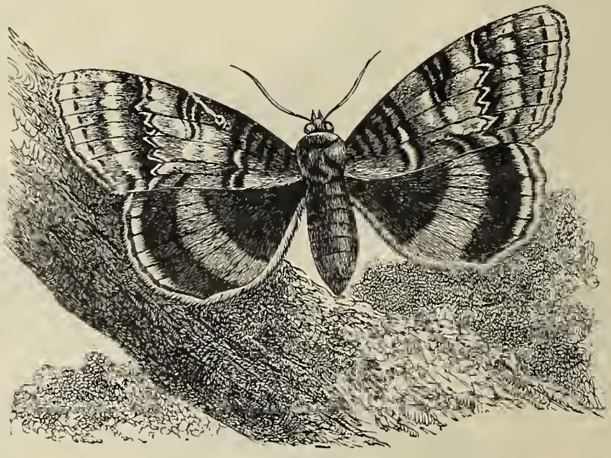
and reddish hind wings. The Moth flies in fields, with a peculiar hovering flight, on summer evenings, and its pale yellow caterpillar feeds on the roots of grasses. The other species are much smaller, and are called "Swifts" by collectors. They are brown or yellowish, with white streaks or spots on the fore wings, and their caterpillars feed on the roots of plants. In some species the Moths have the same peculiar hovering flight as in *H. humuli*, but others fly very rapidly near the ground in the evening.

THE WOOD LEOPARD MOTH.

The great group of Moths known as *Noctuæ*, or Night Moths *par excellence*, consists of many families, of which we will notice only a few of the most important. Speaking generally, their bodies are rather stout, and extend beyond the hind wings; their antennæ are simple (rarely pectinated), and their hind wings are broader than the fore wings, white, grey, or brown, without markings, or with only a dark spot in the middle, and a dark border, and are folded beneath the hind wings in repose like a fan.

The *Leucanidæ*, or Wainscots, mostly frequent marshy localities, and measure about an inch and a half across the wings. The fore wings are ochreous or reddish, rarely with transverse lines, but generally with longitudinal white veins and black dashes, and a few scattered black dots. The caterpillars feed either on grasses or in the stems of reeds.

Many of our commonest Moths belong to the *Apamidæ*. One of these is the Dark Arches (*Xylophasia polyodon*), a brown Moth, measuring nearly two inches across the wings; the abdomen is rather long, and tufted at the extremity. The markings are rather ill-defined, but there is a white line near the border of the fore wings, the lower portion of which forms a W. We find this in many other *Noctuæ*. The hind wings are paler, and where they join the fore wings are smooth and rather iridescent. This Moth is very common in gardens at dusk, and its caterpillar feeds on the roots of grasses. The Cabbage Moth (*Mamestra brassicæ*) is an equally common but much more destructive insect. It is smaller and much darker coloured than the last species, and there is a whitish U-shaped mark on the fore wings. The caterpillar feeds in the heart of the cabbage, and is just as mischievous as those of the common White Butterflies.



THE CLIDEN NONPAREIL.

The family *Noctuidæ* includes a great number of dull-coloured Moths, which expand about an inch and a half across the wings. The fore wings are generally brown, with dark spots bordered with paler. The pale submarginal line does not form a W, and the abdomen is not crested, or tufted. The caterpillars feed on low plants, and many of them, mostly belonging to the genus *Agrotis*, feed on the roots of grasses at or below the surface of the ground, and are called by the Americans "Cut-worms." The Moths belonging to the genus *Triphæna* are handsomer and more conspicuous than the other species of this family, as the hind wings are yellow, with a black band, varying in width according to the species, before the hind margin. They are called "Yellow Underwings."

The *Orthosidæ*, or Chestnuts, include a number of smaller species, expanding about an inch and a

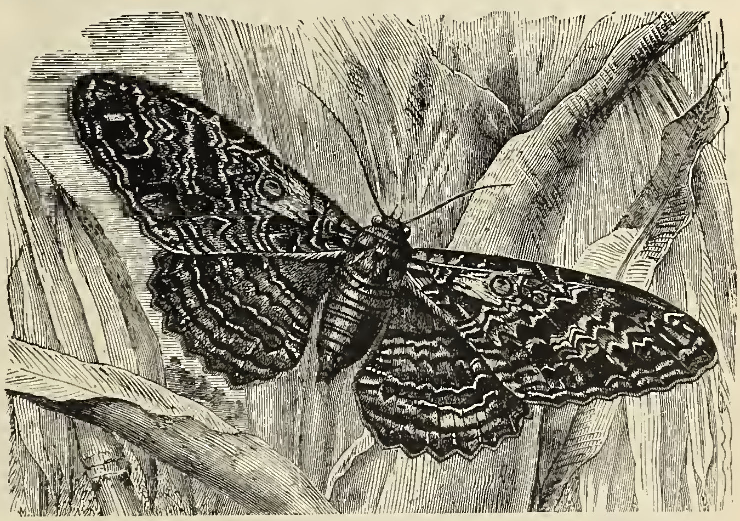
quarter. Most of these have grey, reddish, or yellowish fore wings, and whitish hind wings, and the abdomen is rather short. They may be met with in spring and autumn, and frequent the flowers of the sallow and the ivy. One of the largest species is the Satellite (*Scopelosoma satellitia*), which sometimes expands nearly two inches. The fore wings are reddish, and there is a white or orange spot in the middle, between two small dots. The hind wings are reddish-white. The caterpillar is blackish, with white lines on the back, and white spots on the sides. It feeds on a variety of trees, but will also devour any other caterpillars in whose company it may find itself.

The *Hadenidæ* are a group of Moths much resembling the *Apamidæ*, and generally with the pale subterminal line forming a very distinct W. But the beautiful Angleshades Moth (*Phlogophora meticulosa*) is an exception. The triangular and slightly dentated fore wings are olive-brown, or ochreous, varied with rosy, and the outer pale line is indistinct; the hind wings are yellowish-white.

The *Xylinidæ* are a small family, including, among other genera, the genus *Cucullia*. The Moths belonging to it are called "Sharks" by collectors, and their fore wings and abdomen are long and pointed. The former are generally ochreous or greyish, with hardly any markings, the costa and hind margin alone being bordered with a darker colour. In some Continental species, however, the fore wings are beautifully marked or streaked with silver, and sometimes with green. These Moths expand about one inch and a half.

The *Heliothidæ* are day-flying insects, and one of the commonest species is the Beautiful Yellow Underwing (*Anarta myrtilli*), which is found on heaths. The fore wings, which expand about an inch, are red, with white lines, and the hind wings are orange, bordered with black. Two other species are found in Scotland; but many others are found in Lapland, and other countries in the north of Europe and America. Of these, some have yellow, and others white hind wings.

Several of the *Plusidæ* are also day-flying Moths. The well-known Gamma Moth, or Silver Y (*Plusia gamma*), is one of these. The fore wings are violet-grey, with a silvery Y-shaped mark in the middle. The hind wings are of a paler grey, without markings. Other species of *Plusia* fly in the evening, among which is the Burnished Brass Moth (*P. chrysitis*), the fore wings of which are pale brown, but almost covered by a large irregular brassy-green patch. Most of the other species of the genus are either marked or spotted with silvery, golden, or brassy in a similar manner.



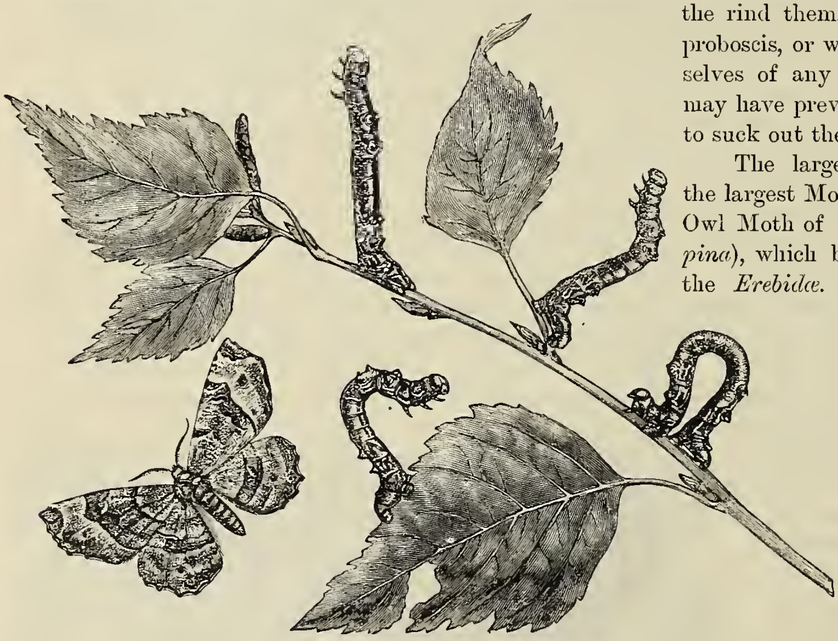
THE GREAT OWL MOTH OF BRAZIL. (ONE-THIRD NATURAL SIZE.)

The *Amphipyridæ* are a small family with rather short and broad wings; and as our representative of it, we have chosen a larger Moth than any *Noctuæ* we have yet noticed —*Mormo maura*—a dark grey insect, with blackish bands, measuring about two inches and a half across the wings. It is very common in gardens on summer evenings, and often flies into houses. Its flight is rather heavy, and it is called "The Old Lady" by collectors.

The *Catocalidæ*, so called from two Greek words, meaning "beautiful beneath," are the largest and handsomest *Noctuæ* found in Europe. The fore wings are grey, varied with lighter and darker zigzag lines and blotches, assimilating them to the appearance of the lichen-covered trunks of trees, on which they prefer to rest. But the hind wings are black, with a pale blue band across, in the rare Clifden Nonpareil (*Catocala fraxini*), while the other species have red hind wings, with black borders, and a black band across the middle. They are all large insects, measuring from two and a half to

four inches across the wings. Many of the European species have yellow hind wings (and these are generally smaller than the red species), and in North America, where there is a much greater variety of *Catocalæ* than in Europe, many species have black hind wings, with a narrow white border. The caterpillars have the first pair of prolegs imperfectly developed, and arch their backs a little in walking. They are sometimes called "Half-Loopers."

The *Ophideridæ* are a family of tropical Moths, generally measuring about three inches across the wings, which are long, rather narrow, and a little pointed. The hind wings are yellow, partly bordered with black, and with a thick curved black mark in the middle. The palpi are long, and curved upwards, and the proboscis is short, and very strong. These Moths are very destructive to oranges in Australia; but it has not yet been ascertained with certainty whether they perforate the rind themselves with their strong proboscis, or whether they avail themselves of any injury which the fruit may have previously received, in order to suck out the contents.



ENNOMOS ILLUSTRARIA AND CATERPILLARS.

The largest *Noctua*, and one of the largest Moths known, is the Great Owl Moth of Brazil (*Thysania agrippina*), which belongs to the family of the *Erebidæ*. It measures nearly a foot across the wings, which are pale grey, with darker markings, and the hind margins are scalloped. But the wings are not remarkable for their breadth, so that the Atlas Moths are larger insects on the whole.

The small family of the *Deltoidæ*, which is sometimes placed with the *Noctuæ* and sometimes with the *Pyrales*, may be illustrated by the "Snout" (*Hypena proboscidalis*), a brown Moth, with rather slender body, and very long palpi, resembling a beak. It measures about an inch and a half across the fore wings, which are broad and triangular, and is a very common insect among nettles.

The *Geometræ* (or Land Measurers) are an extensive group of Moths known as "Loopers" in England, on account of the peculiar structure of the larvæ, which have only ten legs, the two first pairs of prolegs being absent. When they wish to walk, they fix themselves firmly by their last pair of prolegs (the only pair which they possess) and their claspers, and stretch out their bodies to their greatest length; then, fixing themselves by the six true legs, they loosen their hold with the four hinder ones, which they draw closely up to their front legs, thus arching their body into a loop; they then fix themselves again by their hind legs, stretch out the front of their bodies, and proceed as before. This peculiar mode of walking is very rapid; and their mode of rest is not less singular, for they fix themselves by their four hind legs, and stretch their bodies stiffly out, sometimes remaining motionless for hours. In this position they present a remarkable resemblance to a dead twig, and thus often elude the observation of birds and other enemies. The Moths are generally broad-winged insects, with slender bodies. They fly at dusk, but may often be disturbed in the daytime by beating hedges. The wings are rarely dentated or angulated, and are often brightly coloured, the pattern of the fore wings being generally continued on the hind wings.

The family *Urapterydæ* only contains one British species, the Swallow-tail Moth (*Urapteryx sambucaria*), which measures about two inches across the wings; the hind wings are angulated outwards into

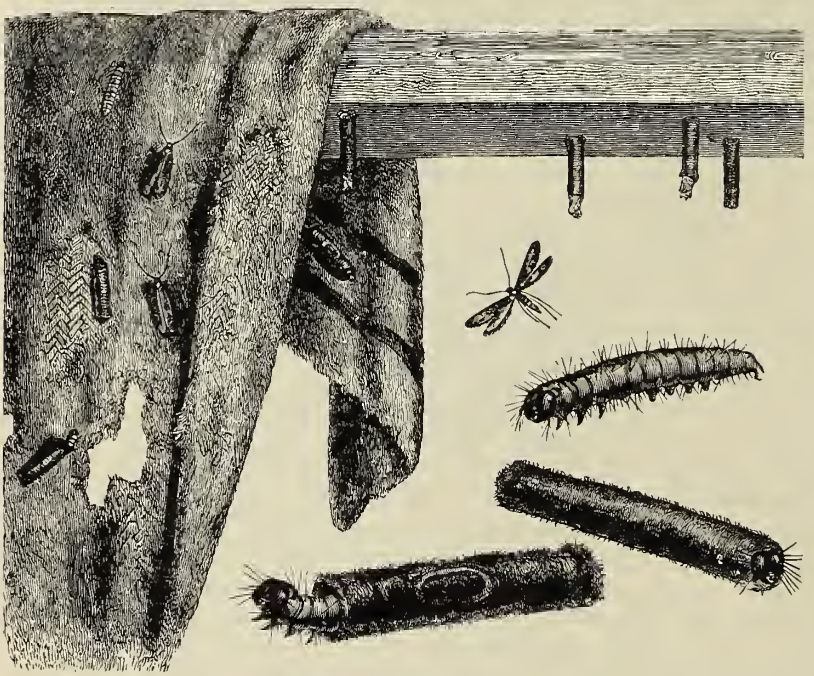
a short tail. It is of a very pale yellow, with two olive-brown lines on the fore wings, and one on the hind wings, and two small brown dots at the root of the tail. The family *Ennomidæ* includes smaller insects, mostly of a yellow colour. Among these is the well-known "Brimstone Moth" (*Rumia cratægata*), so common in hedges. It measures about an inch and a half across the wings, which are sulphur yellow, with rust-coloured spots on the costa. The genus *Ennomos* includes insects of a paler yellow, marked with transverse lines. Their bodies are rather thick, the thorax is covered with a close fur above, and the hind margins of the wings are irregularly dentated. The family *Amphidasidæ* includes dull-coloured Moths with stout bodies. They appear in spring, and one of the commonest is the Pepper and Salt Moth (*Amphidasis betularia*), which is white, speckled with black, and with more or less distinct black costal spots and transverse lines. Some of the allied species have apterous females. The family *Geometridæ* includes a number of broad-winged green species, with whitish transverse lines. Their bodies are rather slender, and the wings, which expand from one to over two inches according to the species, are seldom angulated. These Moths are usually called "Emeralds," on account of their colour. The *Acidalidæ*, or "Waves," comprise a large number of small species, generally of white, ochreous, brownish, or reddish colour, with dusky, or occasionally reddish lines. The Heath Moths, or *Fidonidæ*, fly by day, and several species, tessellated with cream-colour and black, are very common. The *Euschemidæ* are an East Indian group of large Moths, which have only lately been referred to the *Geometræ*, on account of the discovery of their transformations. The Soldier Moth (*Euschema militaris*) is the commonest. It expands about three inches, and the wings are bright yellow, with bluish-black lines and spots, and the fore wings have a broad bluish-black border, spotted with white. The Magpie Moth (*Abraxas grossulariata*) belongs to the family *Zerenidæ*. It is common in every garden, and varies very much, but is generally white, spotted with orange and black at the base of the fore wings, and with an orange stripe across the middle, bordered with black spots on each side. The hind margins of all the wings are spotted with black, and there are several other black spots. The body is yellow, spotted with black. The Moth expands rather more than an inch and a half, and the caterpillar feeds on gooseberry and currant bushes. Several brownish or yellowish Moths, with darker transverse lines, belonging to the families *Hybernidæ* and *Larentidæ*, are found only in winter. It is remarkable that most of these have apterous females, as is likewise the case with some of the *Amphidasidæ*, which appear in very early spring. The large family *Larentidæ* includes a great number of other Moths with brown and white wings, arranged in festooned patterns, which has led to their being called "Carpets." Some of these are white, with black lines; and in the genus *Lobophoræ*, there is so large an additional lobe to the hind wing as to give them the appearance of having six wings, whence they are called "Seraphims" by collectors. These Moths seldom measure more than an inch and a half across the wings, but the great genus *Eupithecia* includes a number of smaller species (called "Pugs"), seldom expanding an inch across the wings, which are generally brown, with darker transverse markings, though a few are varied with white or green. Their small size, and the indistinct character of the markings, render most of the species difficult to distinguish from each other. The *Erateinidæ* are a South American family of Moths, ornamented with bright colours, such as red, black, and white. The fore wings are triangular, and the hind wings are produced and often tailed. These insects look very unlike Moths, and, but for the filiform antennæ, might readily be mistaken for *Erycinidæ*.

The *Pyrales* are a group of small Moths, with rather long wings, and long and slender bodies. The Meal Moth (*Pyralis farinalis*), belonging to the family *Pyralidæ*, is one of the commonest. It measures about an inch across the fore wings, which are dark chocolate brown at the base and tip, and dull yellow in the middle, the colours being separated by white lines; and the hind wings are bluish-grey, with white lines. The caterpillar feeds on flour, as well as on straw, &c., and is sometimes found in meal-tubs. The most beautiful species of this group belong to the *Ennychidæ*. The species of *Pyrausta* are common in waste places in many parts of the country, flying by day. They are small Moths, not exceeding three-quarters of an inch in expanse, and the fore wings are red, with golden yellow lines or spots. The *Hydrocampidæ* are small white Moths, about an inch in expanse, found in marshy places or ponds; the caterpillars feed on water-plants. They are white, with black, and occasionally yellowish, lines or markings, and are known as "China Marks." The *Botydæ* are often called "Pearls," on account of the slightly shining appearance of some of the species. Two of

these (*Botys verticalis* and *urticalis*) are common among nettles, on which the caterpillars feed. They expand about an inch and a half. The former is pale, shining, yellowish-white, with grey markings, and the latter is white, with a row of connected dark spots on the borders, and a row of more separated spots within. The base of the fore wings is yellow, and beyond it are several large dark spots.

The *Crambi* may be known by their very narrow fore wings, and very broad hind wings, which are folded round the body when at rest. The two principal families are *Phycidæ* and *Crambidæ*. The former are small and frequently dull-coloured Moths, many of which live on dried fruits in the caterpillar state, and are consequently common in warehouses. A few years ago an enormous white web, many feet in length and breadth, formed by the caterpillars of *Ephestia elutella*, was found on the wall of a chicory warehouse at York. The *Crambidæ*, or Grass Moths, generally have brown or straw-coloured fore wings, intersected by a white or silvery longitudinal streak; the hind wings are brown, and the palpi project in front of the head, forming a kind of beak. They are easily disturbed when we walk through long grass, but they soon settle again, when the long cylindrical form which they assume when at rest makes them difficult to find. The small family of the *Galleridæ* are remarkable for their caterpillars feeding on wax in bee-hives, where they sometimes cause great mischief.

The *Tortricidæ*, or Bell Moths, may be known by their broad truncated fore wings, which meet together over the back, and give the insect somewhat of the shape of a bell when at rest. The caterpillars generally live in rolled-up leaves, but some feed on fruit, roots, &c.; a few form galls. The maggots which infest our apples and plums are the caterpillars of species of the genus *Carpocapsa*. There is a Mexican species (*C. saltitans*), the caterpillar of which lives in the seeds of a Euphorbiaceous plant, and possesses the faculty of leaping, carrying its house with it. There are about three hundred specimens of *Tortricidæ* found in Britain; one of the commonest is the Green Oak Moth (*Tortrix viridana*). It measures nearly an inch across the fore wings, which are green, whereas the hind wings are brown, and it may often be dislodged in a perfect shower, if an oak tree be skaken.

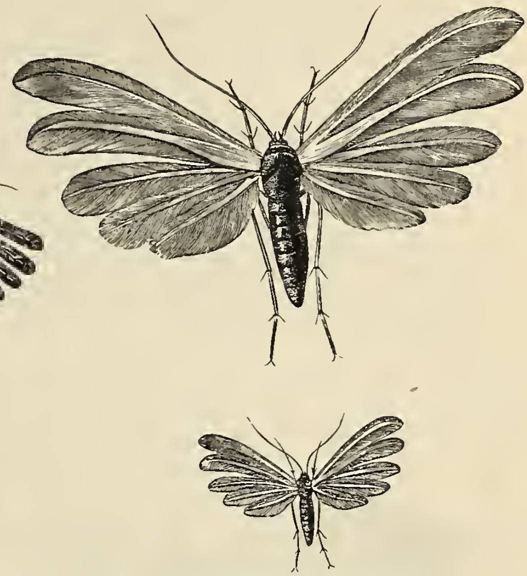


THE CLOTHES MOTH.

The *Tineæ* are a very numerous family of small Moths, to which belong nearly one-third of the Lepidoptera of Britain. Their bodies are slender, and their wings are long and narrow, with very long fringes. There is a great diversity of form, markings, and habits among them. The *Tineidæ*, or Clothes Moths proper, generally feed on dried animal substances, such as cloth, hair, or feathers, though some species feed on corn, &c. They often feed both on and in their food, those that attack clothes forming a tube of the substance on which they feed, in which they live, and which they enlarge when necessary. The *Adelidæ*, or Long Horns, are green, sometimes streaked or spotted with yellow. They may be known by their very long antennæ, which are about three times as long as the expanse of their wings. The genus *Depressaria*, belonging to the great family *Gelechidæ*, contains dull-coloured Moths, with rather broad and flattened bodies. They are rather large for *Tineæ*,

many species measuring nearly an inch across the wings. Many of the larvæ of the *Coleophoridæ* form cases on various plants, like the *Psychidæ ;* those of the *Elachistidæ* live in the stems of grasses. Those of many groups of *Tineæ* live in blotches or galleries made in the interior of the leaves of different plants. Among these are the *Nepticulidæ*, to which family belongs the smallest Moth known (*Nepticula microtheriella*), which measures only about the eighth of an inch across the wings, which are purplish - brown, with a whitish mark beyond the middle. The caterpillar feeds in the leaves of the nut, &c., and twenty or thirty mines may often be seen in a single leaf, according to Mr. Stainton. The perfect insect has never, so far as I know, been observed at large, on account of its very small size. All the specimens in collections are bred.

ALUCITA HEXADACTYLA.
(*Natural Size and Magnified.*)



PTEROPHORUS PENTADACTYLUS.
(*Natural Size and Magnified.*)

The Plume Moths (*Pterophoridæ*) may be known from all other Moths by the fore wings being cleft into two distinct feathers, and the hind wings into three. Most of the species are brown or grey, but the commonest, the White Plume Moth, found in gardens, is nearly pure white. It expands rather more than an inch across the wings, and is a very delicately-formed insect, with long slender legs. The only British representative of the family, *Alucitidæ* (*Alucita hexadactyla*, the Twenty-plume Moth), is a small brownish insect measuring three-quarters of an inch across the wings, each of which is split into six separate feathers. It is common in gardens, &c., and the caterpillar feeds in the buds of the honeysuckle.

FOSSIL BUTTERFLIES AND MOTHS.

On account of their fragile nature, very few Lepidoptera have been found in a fossil state. Some entomologists are said to have described fragments of fossil leaves as the remains of Butterflies, and there is much difference of opinion about other supposed Lepidopterous remains, which are undoubtedly those of insects, some authors maintaining that they are Lepidoptera, while others refer them to the orders Neuroptera or Homoptera. Consequently, as regards remains admitted by all to be those of Lepidoptera, it is not surprising that different entomologists refer them to different genera, and even families. The oldest reputed Lepidopterous fossil is Mr. Butler's *Palæontina oolitica*, but the position of this fossil has been questioned by some authors, though many consider it as Lepidopterous. Mr. Scudder, who has paid special attention to fossil insects, admits only ten species of fossil Butterflies (all of the Tertiary period), one American, and the rest European, which he refers to the families *Nymphalidæ* (*Satyrinæ* and *Nymphalinæ*), *Papilionidæ* (*Pierinæ* and *Papilioninæ*), and *Hesperiidæ*. Most of these have been obtained from Aix, in Provence, but one or two have been found in Croatia and in Western Germany. Scudder regards the nine European species as exhibiting decided Indo-Malayan and Tropical American affinities, one only being related to African, and one to existing South European forms. Concerning fossil Moths still less has been published ; nevertheless, several species have been recorded, belonging to nearly all the leading groups. The oldest of these (*Sphinx snelleni*) is from the Solenhofen Slate, as is also the doubtful Butterfly (*Palæontina oolitica*) to which we have already alluded.

W. F. KIRBY.

CHAPTER XII.

DIPTERA—APHANIPTERA.

DIPTERA—Characters—The Proboscis—Structure—Metamorphosis—Internal Anatomy—Habits—Parasitism—Distribution—Classification—TRIBE NEMOCERA—THE CULICIDÆ, OR GNATS—Metamorphosis—Habits—Blood-thirstiness—The Mosquito—Other Gnats—THE CHIRONOMIDÆ—THE TIPULIDÆ—THE CRANE FLIES, or Daddy Long-legs—The Giant Crane Fly—The Genus *Ctenophora*—Midges—Other Genera—THE MYCETOPHILIDÆ—Fungus Midges—The Army Worm—THE CECIDOMYIDÆ, or Gall Midges—The Hessian Fly—Its Destructiveness—The Wheat Midge—Another Pest—The Galls—Dr. N. Wagner's Observations on the Genus *Miastor*—THE PSYCHODIDÆ—THE BIBIONIDÆ—"Garden Flies"—"Sand Flies"—The *Columbatsch Fly*—TRIBE NOTACANTHA—THE STRATIOMYIDÆ—TRIBE TANYSTOMA—THE TABANIDÆ, or Breeze Flies, or Gad Flies—Habits—The Ox Breeze Fly—The Golden-eyed Breeze Fly—The Clegg—A "Blood-drinker"—THE ASILIDÆ—THE THEREVIDÆ—THE EMPIDÆ—THE ACROCERIDÆ—THE BOMBYLIIDÆ—THE LEPTIDÆ—THE DOLICHOPODIDÆ—THE PLATYPEZIDÆ—THE SCENOPINIDÆ—TRIBE ATHERICERA—THE SYRPHIDÆ—Parasitism—The *Volucellæ*—The Genus *Eristalis*—THE MUSCIDÆ—Characters—The *Tachinariæ*—The *Muscariæ*—The Common House Fly—The Bluebottle—The Flesh Fly—The Greenbottle Flies—The Tsetse Fly—The *Acalypteræ*—Various Genera—The *Phorides*—The *Œstrides*—The *Œstrus bovis*—The *Cephalomyiæ*—*Gastrus*—TRIBE PUPIPARA—THE HIPPOBOSCIDÆ—THE NYCTERIBIIDÆ—THE BRAULIDÆ—*APHANIPTERA, THE FLEAS*—Characters—Classification—Transformations—Habits—Various Species—Their Muscular Energy—Trained Fleas—The Jigger—Its Pernicious Parasitism.

THE Diptera agree with the Lepidoptera in having a suctorial mouth and a perfect metamorphosis, but differ from them in so many particulars that there is no difficulty in distinguishing them—in fact, the order is one of the best characterised in the whole class of insects. They may be defined as insects with a perfect metamorphosis and a sucking mouth; with the prothorax ring-shaped and all the segments of the thorax united into a mass; with only two wings, which are membranous, naked, or more or less hairy, attached to the mesothorax, while the hind wings are represented by a pair of small knobbed organs called halteres. These characters of the wings will serve to distinguish the Diptera at once from the Hymenoptera, with some of which certain species of flies might be confounded at the first glance.

DIPTEROUS INSECTS—VOLUCELLA PELLUCENS AND CERIA CONOPSOIDES.

The mouth, although a sucking organ in the strictest sense of the term, differs completely from that of the Lepidoptera in the nature of the modifications by which its parts are adapted to their peculiar functions, and especially in the fact that, whereas the actual proboscis of the Lepidoptera is formed by a single pair of the fundamental organs of the mouth, that of the Diptera may include and bring into action the whole of those parts. The visible proboscis itself is composed of the lower lip (*labium*), which may be either horny or fleshy in its texture, and is often capable of bending a little way from its base, and of being retracted within a cavity of the under surface of the head. It varies greatly in length, being sometimes quite short and easily concealed, sometimes very long, even much longer than the whole body. The tip is sometimes more or less pointed, sometimes blunt, and then often terminated by a pair of fleshy lips forming a sort of cleft disc, in the middle of which the aperture of the mouth is situated. This structure may be well seen in the common House Fly, or the Meat Fly. But whatever may be its external peculiarities, the proboscis consists of the labium produced into a more or less tubular form, and cleft more or less widely along the upper or front surface. This cleft is closed by the labrum or upper lip, which is elongated so as to reach towards the tip of the proboscis, and, although considerably narrower than the labium, is also curved into the form of a half tube with its concavity turned towards that of the labium.

HEAD OF FEMALE GNAT.

a, antennæ; *l*, labium; *l'*, labrum; *e*, epipharynx; *m*, mandibles; *m'*, maxillæ; *p*, palpus.

Within the tube of the proboscis we find several bristles, often flattened and of a lancet shape, the office of which is to penetrate the tissues of plants and animals, and set free the juices upon which

these insects feed, which are then easily sucked up through the proboscis. These bristles, or lancets, which are the elongated representatives of the organs of the mouth, are somewhat variable in number. When they are most numerous there are five of them, namely, two pairs, representing the mandibles and maxillæ, and an unpaired superior bristle, which is attached to the base of the labrum, or close to it above the pharynx, and is therefore called the *epipharynx*. The number is reduced by the suppression of some of the bristles—usually to three, one pair and a single superior one—and it is then a question whether the upper unpaired bristle is still to be regarded as the epipharynx, or whether the latter is suppressed and the third bristle composed of the two representing the mandibles united into a single organ. The latter view is the one now generally adopted. The number of bristles may vary even in the two sexes of the same species, as is the case in the common Gnat, of which the female alone possesses the full complement. The labium itself has no palpi, but the bristles representing the maxillæ have these appendages, which are frequently of considerable length and composed of several joints. The palpi project from near the base of the proboscis, from which, indeed, they actually spring in many instances (as, for example, in the common House Fly). This is due to the fact that in these insects the part of the maxillæ bearing the palpi is amalgamated with the base of the labium into a single mass.

The head in the Diptera is very freely attached to the front of the thorax by a short and usually slender neck, an arrangement which renders it very movable; it is generally of a rounded form, but not unfrequently flat or even concave behind. The compound eyes are well developed, except in a few forms, in which they are rudimentary or altogether wanting. They are usually large, often covering nearly the whole upper surface of the head, and leaving only a small triangular space on the top for the three ocelli, which are generally present, and another small space in front for the attachment of the antennæ. The eyes are generally larger in the males than in the females, and often meet in the middle line, whilst in the females they are separated by a narrow band.

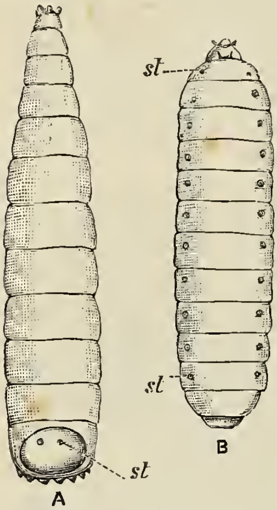
The antennæ, which are generally inserted upon the face between the eyes, vary considerably in size, form, and structure, but we can distinguish two principal types of these organs. In the one (see figure of head of female Gnat on p. 70), the antennæ are more or less elongated and composed of a considerable number of joints, when they are either thread-like or beaded, and often, especially in the males, hairy or feathered throughout; in the other, they consist apparently only of three joints, of which the last is usually a good deal longer than the others, and not unfrequently shows signs of its being really composed of several joints in the shape of notches or transverse lines. These antennæ sometimes project in front of the head, and sometimes hang down close in front of the face. The third joint is very commonly furnished with a long bristle, which may be jointed, and thus indicates that it is a continuation of the ordinary jointed antennæ. This bristle, which is often hairy or feathered, may spring either from the extremity or from the back of the third joint (see Vol. V., p. 284, Fig. 5, E).

As in the Lepidoptera, the three segments of the thorax are soldered together to form a single mass. The mesothorax, as bearing the wings, is most largely developed; the prothorax is generally reduced to a very small ring; and the metathorax is usually confined to the hinder surface of the thorax. The hinder part of the mesothorax is cut off by an impressed line, and forms a distinct scutellum. The wings, of which, as already stated, only the first pair are developed as organs of flight, although sometimes dark-coloured or spotted, are generally transparent, and either composed of naked membrane or more or less clothed with hairs. The veins for the most part run, branching more or less, through the length of the wing, but in many species there are cross-veins which enclose complete cells, like those of the Hymenoptera, although we never find, as in the latter, a stigma with a regular system of cells in its vicinity. Close to the base of the inner margin of the wing, in a great number of Diptera, we find the margin of the membrane cut into one or two small lobes by notches of variable depth. The outer one, which is clearly a portion of the wing, has been called the *alulet*; the inner one, which is attached to the thorax, is the *scale* (*squama*), and, when most developed, forms a sort of roof-like covering for the *halteres*, or appendages of the metathorax. The latter, the nature of which has been the subject of considerable discussion, are now generally regarded as representing the hind wings. They are small organs resembling the clapper of a bell, composed of a thin stalk bearing a knob at its

extremity. These organs are in a constant state of vibration, but what their special function in the economy of the insect may be is unknown.

The three pairs of legs, which are articulated to the lower part of the thorax, exhibit a considerable variety of development, being sometimes of moderate length and stout or even thickened, sometimes excessively long and slender, and exhibiting every intermediate form. They are, however, always articulated to the thorax by a conical coxa, have a ring-shaped trochanter, and five-jointed tarsi, of which the first joint is generally much longer than any of the rest: the last joint has at its extremity a pair of claws, and either two or three membranous appendages (*pulvilli*).

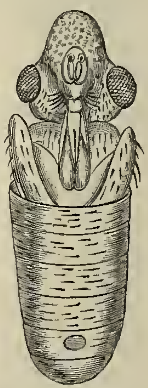
The abdomen, which may be attached to the thorax either by its whole base or by a slender stalk, consists of from five to eight segments, but generally shows no external peculiarities, except the appendages to the generative organs which frequently project from its apex, and are sometimes very complicated in the males.



DIPTEROUS LARVÆ: A, MUSCA MEDITABUNDA, HEAD NOT DISTINCT; B, BOLETOPHILA FUSCA, WITH A DISTINCT HEAD.
st, Stigmata.

Throughout the order the larvæ are footless grubs, generally with a soft body, but sometimes leathery, or even nearly horny. Many of them possess a distinctly marked head, which may bear ocelli, but in the majority the head does not differ from the other neighbouring segments, within which it can be retracted. The mouth is frequently provided with a pair of horny hooks, by means of which the larvæ cling to the objects from which they obtain their nourishment. This consists in all cases of fluid materials derived from animal and vegetable substances. The larvæ frequently live in the substance upon which they are feeding; others reside in the water, and many are parasitic.

When the larva is full grown the change to the pupa state takes place in two different ways. In some the larva skin is cast, and the pupa makes its appearance in a form more or less resembling that of the Lepidoptera, that is to say, the wings, limbs, antennæ, and other parts of the body are shown, only enclosed within a membrane; while in others the larva skin is retained and becomes hardened, so as to form a case within which the insect changes into a pupa. The escape of the perfect insect in these latter cases is usually effected by the separation of one end of the case, like a sort of cap, the agency by which the rupture is effected being, in many cases if not in all, a peculiar bladder-like inflation of the forehead which is afterwards effaced. Many of the free pupæ are provided with sharp hooked processes upon the head and thorax, which are of service to them in making their way out of their places of shelter when about to give birth to the perfect insect; those of the species living in water are active, and swim vigorously by the action of the abdomen.


COMMON HOUSE FLY EMERGING FROM THE PUPA.

The respiration of the larvæ is effected by stigmata, but there is considerable difference in the arrangements of these organs. Many larvæ, including the great majority of those provided with a distinct head, have the stigmata, or breathing pores, placed along the sides of the body, two on each segment, as in the majority of the insects which have already been described; but in a still greater number, including all those commonly called headless larvæ, or in common parlance, *maggots*, the stigmata are indeed often indicated on the sides of the segments, but these are not perforated, and the only efficient respiratory openings are a pair of stigmata situated at the hinder end of the body, usually upon a flattened surface which terminates it posteriorly. Some head-bearing larvæ, however, which live in water, such as that of the common Gnat, have their sole efficient respiratory aperture situated at the hinder end of the body, where it forms a longish tube, the extremity of which can be brought to the surface of the water for the admission of air to the tracheæ, and a somewhat similar provision is met with in some headless larvæ.

In a good many species of the order the larvæ are hatched within the body of the mother, and in one whole group, which is distinguished by other peculiarities, they are not only hatched but

DIPTEROUS FLIES.

A, Tipula hortulana; B, Ctenophora pectinicornis; C, Stratiomys chamæleon; D, Tabanus bovinus; E, Asilus germanicus; F, Volucella pellucens; G, Syrphus pyrastri; H, Chrysops cæcutiens; I, Eristalis tenax; K, Tachina grossa.

retained and nourished in the egg-passages until they are ready to pass into the pupa state, and are born in this condition.

As regards the internal structure of the Diptera, it may be mentioned that, like the Lepidoptera, they possess a sucking stomach which originates from one side of the œsophagus; that they have four, or sometimes five, Malpighian vessels, which not unfrequently unite to form one or two ducts by which their secretion is discharged into the intestine; that the two main trachean stems exhibit bladder-like dilatations, which are often of considerable size in the base of the abdomen; and that the central nervous chain varies greatly in structure in accordance with the general form of the body, the elongated species having three distinct thoracic and five or six abdominal ganglia, while in some stout-bodied flies the whole of the ganglia seem to be united into a single mass.

The Diptera are for the most part active day-flying insects, like the Hymenoptera, which some of them closely resemble in appearance and in haunting flowers, upon the sweet juices of which they feed. There is a further resemblance between the Diptera and the Hymenoptera in the prevalence of the habit of parasitism in certain groups of both; and in both orders we find species whose larvæ reside and feed in the interior of excrescences produced upon plants by the irritation of their presence. In the Hymenoptera, however, we have no examples of the bloodthirsty propensities which characterise so many Diptera. Apart from these and some other forms which are either annoying to ourselves or injurious to our property, the Diptera must be regarded as acting a beneficent part in the economy of nature. Thus, so far as we are concerned, the parasitic and some predaceous species act as a check upon the multiplication of many other insects which are enemies to the gardener and agriculturist; while a great number of others seem to have a special mission to clear away all sorts of decomposing animal and vegetable matters which, if left, would seriously contaminate the air.

From the imperfect knowledge that we possess of the exotic species of this order, it is not an easy matter to arrive at any trustworthy estimate of the total number of species included in it. Dr. Schiner, of Vienna, estimates the known European species at about 9,000, and these he regards as not more than a twentieth part of the whole. Allowing for probable exaggeration in the estimate of European forms, this would give 150,000 or 160,000 as the total Dipterous population of the globe.

As regards their geographical distribution, the Diptera show a remarkable uniformity, the principal families being generally represented in most regions, and many genera, and even species, having an exceedingly wide distribution. The largest and finest species in this, as in other orders, are generally inhabitants of warm climates. In their geological history, the Diptera agree generally with the Hymenoptera. No Palæozoic Diptera have been recorded. Among the secondary rocks the Rhætics are the earliest in which remains of Diptera are supposed to occur, and these are regarded as very doubtful. The Lias of Schambelen in Switzerland, which has yielded Professor Heer such an important assemblage of insects of various orders, contains no Diptera, and it is not until near the close of the Mesozoic period that undoubted remains of Diptera were preserved in the lithographic slates of Solenhofen and in the Purbecks of Dorsetshire and of Wiltshire and Buckinghamshire. These represent several still existing families. A few fragments of wings occur in the Wealden; but in all Tertiary deposits Diptera occur in constantly increasing number and variety, but all referable to families and usually to genera still living on the earth.

The Fleas (*Aphaniptera*) have of late years commonly been regarded as aberrant members of the order Diptera, but for various reasons we have preferred here to revert to the old view, never entirely abandoned by naturalists, that these insects form a distinct order. The remainder, characterised in general as above described, may be divided into two groups, in accordance with a very important difference in their mode of reproduction. In the first and most typical group, the females produce their young either in the egg state or as young larvæ; in the second, the hatched young are retained within the oviduct until they are full grown, and only extruded when they are just about to pass into the pupa stage. These latter, to which the name of PUPIPARA has been given, differ from the rest of the order in several points of structure; thus, the head is either very closely applied to the front of the thorax, or actually immersed in a cavity formed in that part for its reception, the antennæ are excessively short, and usually immersed in cavities of the front of the head, and the maxillæ form a sort of sheath for the labrum, the actual piercing organ consisting only of these three bristles. The remainder, which exhibit, with

many minor modifications, the normal structure of the order, may then constitute a great group under the name of DIPTERA GENUINA, which is already sufficiently characterised.

The classification of the Diptera is a matter of some difficulty, and several different systems have been proposed. Until of late years, however, the order was usually divided into two main sections, the Nemocera and the Brachycera, or long and short-horned types; but other arrangements have been proposed, generally founded, more or less, upon the character of the metamorphosis, the most complete of which is that invented by MM. Brauer and Schiner, which rests almost wholly upon the study of the preparatory states of the insects. This classification, however, we shall not adopt here, partly because the groups thus formed cannot always readily be characterised by peculiarities of the perfect insects, and partly because it is quite uncertain how far minor peculiarities of the larvæ and pupæ are to be regarded as of importance in classification. The arrangement of the families here followed is very nearly that adopted by Dr. Gerstäcker in the "Handbuch der Zoologie," but we have introduced some higher divisions, which are the same as those proposed many years ago by Latreille and adopted by Professor Westwood in his admirable "Introduction to the Modern Classification of Insects." The characters distinguishing the Pupipara, the lowest of our divisions or tribes, from the rest of the Diptera, have already been indicated, and we have therefore now only to consider the "Diptera genuina." These may form four tribes.

1. NEMOCERA, having the antennæ usually composed of from ten to seventeen joints, but sometimes of only six, thread-like or beaded, and the palpi of four or five joints, the cross-veins in the wings usually few or altogether wanting, and the halteres uncovered. The larva is furnished with a more or less distinct head, and gives origin to a free pupa.

2. NOTACANTHA, having the antennæ composed of not more than twelve joints, which, when most numerous, are sometimes nearly equal, forming a thread-like antenna, as in the preceding division, but more commonly constitute apparently a three-jointed organ, of which the third joint is ringed; the palpi of not more than three joints; the veins of the wings usually forked and with cross-veins, and the halteres uncovered. The larva has a more or less distinct head, and the pupa is enclosed in the dried larva skin, from which it escapes, when mature, through a slit in the back.

3. TANYSTOMA, in which the antennæ consist apparently of three joints, but often with indications of articulations in the third joint, and with a terminal bristle; the palpi of not more than two joints; and the mouth usually more perfect than in the preceding group. The larvæ have a more or less distinct head, and produce free pupæ.

4. ATHERICERA, having the antennæ composed of three joints, of which the third shows no indication of rings, but is furnished with a bristle which is often more or less jointed; the proboscis kneed, usually retracted and concealed when not in use; the palpi of a single joint, and the mouth with only two or three bristles. The larvæ have no distinct head, and the pupa is enclosed within the dried larva-skin, which contracts into an oval form.

5. PUPIPARA, already characterised (p. 73).

TRIBE I.—NEMOCERA.

As already described, the Nemocera have thread-like or beaded antennæ, and these organs are usually of considerable length, and composed of somewhat numerous joints. In many cases, especially in the males, they are fringed or surrounded with long hairs, which give them a plumose appearance. When the antennæ are short, the palpi furnish distinctive characteristics, they being either four or five-jointed, whereas the palpi of the succeeding tribes never contain more than three joints, one of which is so much more developed than the others that the organs appear one-jointed.

The insects belonging to this group are numerous and present a considerable variety both of character and habits, and their classification has been variously treated by different authors, some regarding them as constituting a single great family, whilst others divide them into from two to a dozen such groups. We shall here adopt a division into eight families.

FAMILY I.—CULICIDÆ, OR GNATS.

The Gnats or Mosquitoes may be at once distinguished from all the other Nemocera by their long, slender, horny proboscis, which may be half as long as the body of the insect, and is usually

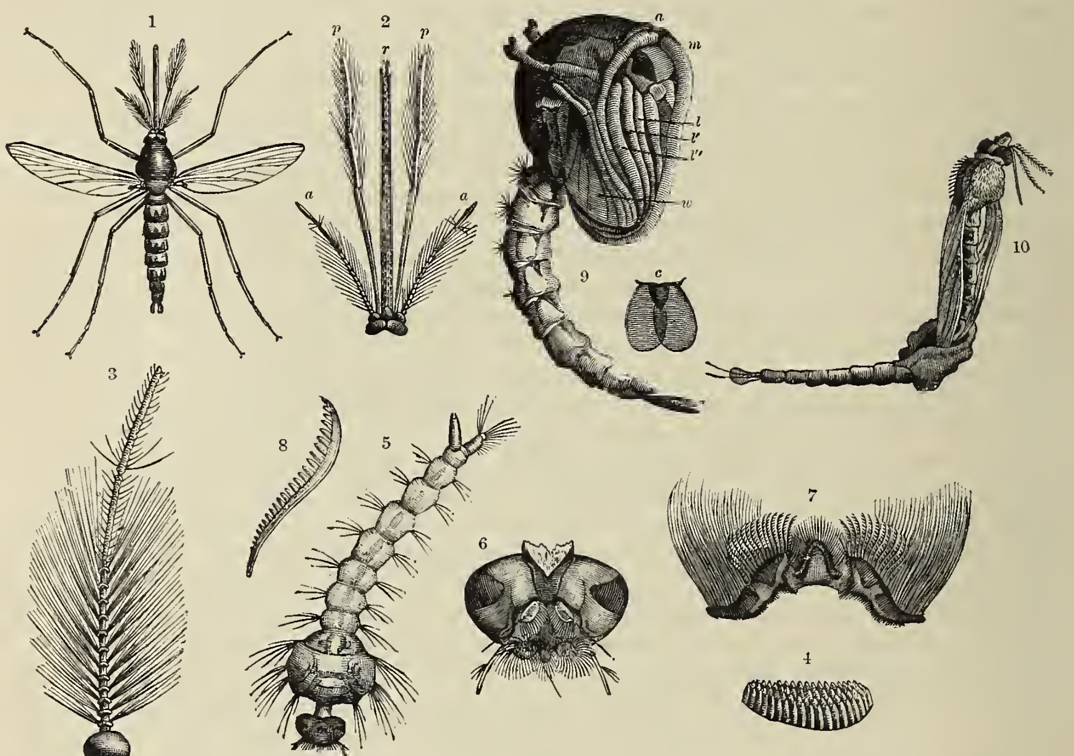
slightly thickened at the tip. This proboscis in the females contains all the parts that are ever found in a Dipterous insect, the bristles representing the mandibles and maxillæ being present and free, together with the fifth bristle or epipharynx. The mandibles are wanting in the males. The maxillæ have a pair of palpi, of four joints, and comparatively short in the females, of five joints, very long and often more or less hairy in the males. The antennæ are long and slender, composed of fourteen joints, and furnished with whorls of hairs, which become very long and dense in the males, giving them a beautifully feathered appearance. The head is small, and bears a pair of lunate eyes, but no ocelli; the thorax is stout; and the abdomen slender and delicate; the legs are very long and thin, and the veins of the wings are densely clothed with scale-like hairs.

These insects, which are only too well known for their blood-sucking propensities and the intense irritation often produced by their bites, are inhabitants of the water in their preparatory state, and it is accordingly in the neighbourhood of water and in wet seasons that they especially abound. The eggs, which are of an elongated form, are deposited by the female, with the assistance of her hind legs, upon the surface of the water in a small boat-like mass, the eggs being arranged and closely packed together side by side with their pointed end uppermost (Fig. 4, p. 76). From the shape of the eggs, which are a little broader at one end than at the other, the whole mass of eggs necessarily acquires a slight curve like that of a shallow spoon, and the larger ends being downwards, the concavity of the spoon is above, and the little collection of eggs floats securely like a boat upon the surface of the water, until the larvæ are hatched. This soon occurs in favourable weather, and the larvæ descend into the water, where they may be constantly seen during the spring and summer, swimming about with great agility by a violent jerking motion of the body, or suspending themselves from time to time head downwards at the surface of the water, for the purpose of breathing through a curious air-tube, with which they are provided near the tail (Fig. 5, p. 76). This tube springs from the eighth segment of the abdomen, and its apex is surrounded by a circlet of bristles, which, by closing, prevents the entrance of water when the larva is submerged, but opens like a little star when the orifice is brought to the surface of the water, and thus gives free ingress to the air, and at the same time assists in suspending the larva from the surface. The terminal segment of the abdomen, which is beyond the origin of this tube, is fringed with bristles and terminated by five slender, conical plates. The larva has a distinct rounded head, which is furnished with a pair of antennæ, and between these with a pair of jaws fringed with very curious bristles (Figs. 6, 7, 8, p. 76). The latter organs create a sort of whirlpool in the water, which serve to convey to the mouth of the insect the floating particles of more or less nutritive matter that come within its reach. These curious larvæ change their skin three times, and then become converted into pupæ (Fig. 9, p. 76), in which the parts of the perfect insects are rudely indicated; they continue to swim about by the agency of the abdomen, which is terminated by a pair of thin leaf-like organs. In this condition the insects of course no longer take any nourishment, but, like the larvæ, they still suspend themselves at the surface of the water in order to respire air; their position when thus engaged is, however, the reverse of that of the larvæ, the breathing-organs being now two short tubes, like truncated horns, which spring from the sides of the thoracic region. When the perfect Gnat is ready to emerge the pupa comes to the surface of the water, and remains there quite still, until the skin of its back, which is exposed to the air, dries and splits longitudinally. The perfect insect then slowly emerges, disengaging one part of its body after the other from the pupa-skin, which, during this operation, acts the part of a boat or raft, for the support of its previous inmate, until the wings of the latter have acquired sufficient firmness to enable it to rise into the air. In rough weather these frail boats often prove insufficient, and many Gnats get drowned before their wings are dried (Fig. 10, p. 76).

After their emergence, these delicate creatures, or at least the males, pass their time in a series of aërial dances, in which great swarms of them may often be seen engaged; in fact, so numerous are the insects in certain seasons and localities, that their swarms have sometimes the appearance of great smoke clouds surrounding and ascending from some lofty building, such as the spire of a church. As each female lays about 300 eggs, and the development of the insects occupies only four weeks, it is easy to understand how this extraordinary number of individuals may be produced by the successive generations in the course of the spring and summer, if the external conditions are favourable. The females of the last generation of the season, after fecundation, retire to sheltered

situations, where they pass the winter, coming forth again in the first mild weather of spring to deposit their eggs and continue the species.

As has already been stated, it is only the females (which have all the parts of the mouth developed) that feast upon the blood of vertebrate animals; the males feed only upon the nectar of flowers, to which also the females will resort. They never seem to miss a chance, however, of procuring the more nourishing food, and the irritation caused by their bites is pretty well known to most people. Our common English Gnat produces sufficiently disagreeable effects, but the Mosquitoes of warm climates and of high northern latitudes are among the most formidable of insect-plagues, and even in Central Europe the Mosquitoes seem to possess a wonderful power of irritation. Their mode of operation is well described by Professor Westwood:—"Thirsting," he



THE HOUSE GNAT. (*Culex ciliaris.*)

1. The male, enlarged. 2. Head of the male, magnified; *a*, antennæ; *p*, palpi; *r*, proboscis. 3. Antenna of the male still more magnified. 4. Egg-float. 5. Larva, magnified. 6. Head of larva still more magnified. 7. Mandibles and labrum further enlarged. 8. One of the comb-like hairs from the mandibles. 9. Side view of pupa, magnified; *a*, case of antenna; *l*, *l'*, *l''*, cases of the limbs; *w*, wing-case; *c*, caudal leaves, front view. 10. Gnat issuing from pupa.

says, "for its evening meal, the little animal enters our apartments, and, instead of whirling, like the Moths, around the light, it betakes itself to its employment, sounding an approach, however, by a tolerably loud humming,* which, in our chambers, at least, is often sufficient to banish sleep. Taking its station upon an uncovered part of the skin, with so light a motion as not to be perceptible when it alights (although it will not hesitate to make its attacks occasionally through our thick clothing), it lowers its rostrum and pierces the skin by means of its exceedingly slender needle-like lancets, which are barbed at the tips, and, as by degrees it pushes these deeper into the skin, the lower lip or sheath, in which they were enclosed when at rest, becomes more and more elbowed towards the breast, until the whole length of the lancets is introduced into the skin. It is supposed that, at the same time, it instils into the wound a venomous liquid, which, while it enables the

* It is only the females that produce this humming or trumpeting noise, and it has been calculated that the wings vibrate 3,000 times in a minute.

blood to flow faster, is the chief cause of the subsequent irritation." The insect, when undisturbed, will gorge itself with blood until the abdomen is considerably distended.

The habits of all the insects of this family are so nearly alike that the above description, which applies specially to the common English species, will serve pretty well for them all. Of the typical genus *Culex* we have about nine British species, the commonest of which are the House Gnat (*C. ciliaris*) and the Ring-footed Gnat (*C. annulatus*), both of which frequent houses. The latter is rather the larger, and appears to produce a greater amount of irritation by its bite. The Wood Gnat (*C. nemorosus*) frequents woods and does not come into houses. *Culex pipiens*, with which our commonest Gnat was formerly identified, is especially an inhabitant of Northern Europe. It was originally described by Linnæus from Lapland, where it abounds in company with several other species, some of which occur in this country. Its bite is said to be extremely irritating. The term Mosquito, signifying merely a little fly, is applied in many places to other biting insects than the Culicidæ, but the insects against which travellers have generally to take precautions belong to the present family. Many species have been described from different parts of the world.

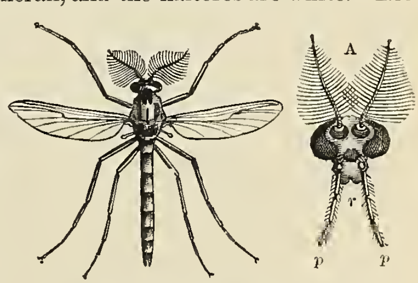
FAMILY II.—CHIRONOMIDÆ.

The remainder of the insects forming the first tribe of Diptera, which are frequently united into a single great family, differ from the Gnats in the structure of the proboscis, which is short and fleshy, and has the extremity generally furnished with a pair of fleshy lips, whilst the internal organs are generally reduced in number, or more or less amalgamated with each other and with the proboscis. The eyes are generally rounded or more or less oval, and the ocelli, with very few exceptions, are deficient as in the Culicidæ.

The CHIRONOMIDÆ, which we place as the first family of this group, are more or less Gnat-like insects, with slender antennæ considerably longer than the head, very strongly feathered, especially in the males, in which they usually form two triangular bushes projecting from the front of the head. In the males these organs usually consist of thirteen joints; the females have a smaller number of joints, and their antennæ are usually shorter. The eyes are lunate, and there are no ocelli; the legs are very long and slender, and the tibiæ are not armed with spines; the veins in the wings closely resemble those of the Gnats.

Many of these insects are so Gnat-like that they are very commonly termed Gnats. They resemble the members of the preceding family also in many of their habits, especially in having the larvæ and pupæ aquatic, and in the custom of collecting in great swarms and dancing in the air. They do not, however, in general possess the formidable offensive weapons of the Gnats, and most of them are quite harmless. The best English name for them is that of Midges.

The nearest approach to the true Gnat is made by the genus *Corethra*, one species of which (*C. plumicornis*) is very generally distributed in Britain. It is a small insect, about a quarter of an inch long, of a brown colour, with the antennæ paler and banded with brown, and the feathery hairs of the male antennæ entirely pale; two bands on the sides of the thorax, and the halteres are white. The larva of this species, which may be met with almost everywhere in standing waters, is so beautifully transparent that it can hardly be distinguished from the water in which it swims. It is long and slender, with the thoracic region considerably enlarged; at the extremity of the body there is a delicate fan of hairs which appears to have a respiratory function. The pupa much resembles that of the Gnat, but is straighter, and has the respiratory appendages of the thorax pointed.



CHIRONOMUS PLUMOSUS. (*Enlarged.*)

A, head magnified, showing the antennæ, the proboscis (*r*), and the palpi (*p*).

The genus *Chironomus*, which gives its name to the family, includes an immense number of species; one hundred and ninety-five are recorded by Mr. Walker as inhabitants of Britain. The commonest of all is *Chironomus plumosus*, a larger insect than the preceding, measuring from one-third to half an inch in length, of a pale brownish-yellow colour, with three blackish stripes on the thorax, the palpi and antennæ black, and the abdomen blackish-grey, with a white band on the hind margin of each segment. The larva, which

abounds almost everywhere in stagnant water, is worm-like and of a blood-red colour; it is, in fact, the animal known to anglers as a bait under the name of the "Bloodworm." The pupa resides in the water, and has five long pilose branchial filaments on each side of the thorax, and the extremity of the body terminated by a long pencil of hairs.

Ceratopogon is another extensive genus of which about eighty European species are known. They also have beautifully feathered antennæ, but the mouth is more perfectly developed than in the rest of the family, the epipharynx and maxillæ being free, pointed, lancet-like organs, with which the females of some of the species are able to draw blood. They are generally very minute. The larvæ exhibit a considerable variety of habits, some living in the ground, some in water, and some under the bark of dead trees. This is the case with the commonest British species (*C. bipunctatus*), a little creature not more than a twelfth of an inch long, of a pitchy colour, with a clothing of yellowish hairs upon the thorax, and a white dot upon the fore margin of each of the transparent wings. The body of the larva is cylindrical, slightly thickened in front, and each segment is furnished on the back with two clubbed bristles; the pupa is shorter, much broader in front, and has its abdomen partly encased in the cast skin of the larva.

FAMILY III.—TIPULIDÆ.

This family includes the largest species of the tribe, and, indeed, some of the largest Diptera. None of them have feathery antennæ like those common in the two preceding families, but these organs are long, or, at any rate, longer than the head, thread-shaped, and generally furnished with short hairs, although in a few species they are pectinated. The number of joints is usually thirteen, but sometimes more. The eyes are rounded or oval, and the ocelli are wanting. The front of the head is usually produced into a sort of beak distinct from the short fleshy proboscis; the palpi are four-jointed, and have the last joint very long and sometimes ringed; the legs and abdomen are long, and the wings have numerous veins, with some cross veins forming cells upon the disc of the wing. The larvæ in general live either in the ground or in rotten wood; and the pupæ, which are found in the same situations, are provided with spines upon the abdominal segments, enabling them to push their way out into the air when the perfect insect is about to emerge. The preparatory states of a few species are, however, passed in the water.

We may take as typical examples of this family the well-known insects which are commonly called Daddy Long-legs, or Crane Flies (*Tipula*, Pl. 62, A), and may be met with in abundance in meadows during the summer and autumn. The number of species is considerable, about fifty having been described as inhabitants of Europe. The largest of them which is found in Britain is the Giant Crane Fly (*Tipula gigantea*), the female of which measures about one inch and a quarter in length. The commonest British species (*T. oleracea*) is rather smaller, the largest females not reaching the length of an inch. The insect is of a hoary brownish colour, with four brown streaks on the back of the thorax, and has the very long legs of a pale brownish-yellow colour, with the thighs, tibiæ, and tarsi blackish towards the end. The female lays a great number (about 300) of small, shining black eggs, which are deposited in or on the ground, by means of an ovipositor composed of several valves, and she may frequently be observed flying over lawns or other grassy ground, and every now and then pushing down her abdomen so as to reach the earth. The larvæ hatched from these eggs, which are commonly known as grubs, and sometimes as "leather-jackets," from the texture of their skin, are soft cylindrical creatures of a dingy greyish or brownish colour, destitute of feet, but furnished with several conical, fleshy appendages at the hinder extremity of the body. When full grown they are from an inch to an inch and a half in length. These larvæ, and probably those of other species of *Tipula* which also live in the ground, feed upon the tender rootlets of grass and other herbage, and also attack young plants. In this way they often do an immense amount of mischief, laying bare large patches of meadow and destroying great quantities of young corn. The change to the pupa state takes place underground, and the pupæ, which are naked, have a pair of respiratory tubes springing from near the head. When about to give birth to the imago, they push themselves, by means of the spines on the segments already mentioned, up to the surface of the ground, from which they finally protrude perpendicularly for a good portion of their length; the pupa case then splits, and the perfect insect emerges. *Tipula hortulana* is common in gardens.

Some nearly allied species, forming the genus *Ctenophora*, have the antennæ very beautifully pectinated in the males, each joint, from the fourth onwards, having either one or two pairs of branches. The *Ctenophoræ* are more robust insects, and have a more rapid flight than the *Tipulæ*, and they are generally adorned with brighter colours, principally tawny or ferruginous yellow in combination with black. These insects reside in wooded localities, and their larvæ feed upon rotten wood. The largest and commonest British species is *Ctenophora pectinicornis* (Pl. 62, B), the female of which is nearly an inch long. Its general colour is black, with two yellow streaks on the thorax, and with the abdomen tawny, but with the extremity and a streak down the middle black.

The larvæ of the genus *Trichocera*, three species of which are generally distributed in Britain, also live in decayed wood and in fungi and decaying vegetables. They are much smaller and more delicate than the insects hitherto referred to, and, in fact, are true Midges, which may be distinguished as WINTER MIDGES, from their not only surviving the winter in the perfect state, but also taking advantage of any spell of mild weather to come out and perform the usual Midge-dances in great companies. The commonest species is *T. hiemalis*, which may almost constantly be found in mild weather upon the glass of windows even in large cities.

The family includes many other small and often more or less Midge-like species, the larvæ of most of which live in the earth, or in fungi and rotten wood. Of these the genus *Limnobia* alone possesses over fifty British species. The larva of a European species of that genus (*L. replicata*) is aquatic in its habits, and has its body furnished with numerous long filaments, which appear to be supplied internally with air tubes, and are probably branchial in their function. In the genus *Ptychoptera* also, of which two or three species inhabit Britain, the preparatory stages are passed through in the water, the larva being a long, worm-like creature, much narrower towards the posterior end, from which springs a very long and slender tube serving for respiratory purposes, conveying air to a pair of tracheæ which extend through the body, whilst in the pupa a similar delicate air tube originates from the anterior extremity.

FAMILY IV.—MYCETOPHILIDÆ.

The insects of this family, which may be called FUNGUS MIDGES, are of small size, and generally of very delicate structure. They have usually shorter antennæ than the insects of the preceding families, but these organs are longer than the head, slender, simple, and composed of fifteen or sixteen joints; the eyes are round, and there are on the vertex either two or three ocelli; the front of the head is not produced; the palpi are long and four-jointed, but the last joint is not greatly elongated and ringed; the wings have but few veins and no cells on the disc, and the legs are of moderate length with elongated coxæ and the posterior tibiæ spined. In one genus (*Epidapus*) both wings and halteres are deficient.

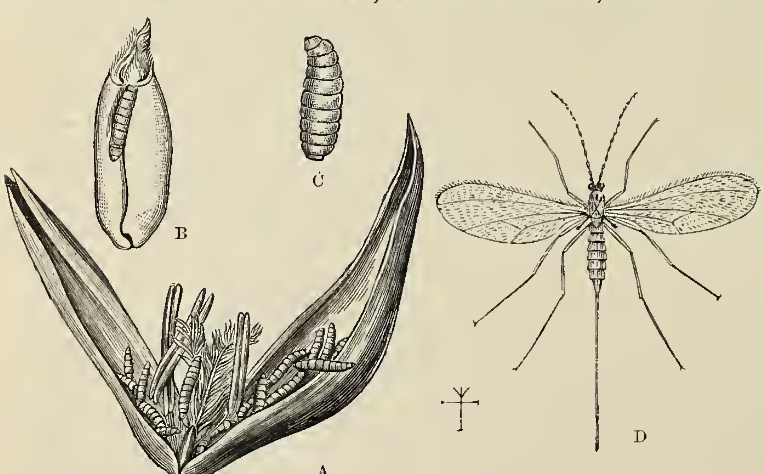
The perfect Mycetophilidæ are very active insects, generally found in damp situations upon herbage, upon which they run freely and are able to spring by means of their hind legs. The species are numerous and generally Midge-like. They often come into houses, and may be found upon the windows. Although the antennæ are usually short, they are considerably elongated in some genera; in *Bolitophila* and *Macrocera* especially they are very long, in the latter sometimes three times the length of the body.

The larvæ generally feed upon fungi of various kinds, but especially upon the *Boleti* which grow upon trees; those of some species, however, are found under the bark of dead trees and about decaying vegetable matter of different kinds. Most of the larvæ, which are slender vermiform creatures, spin a delicate silken web, within which they live, and many of them are gregarious in their habits. The larvæ of *Rhyphus fenestralis*, which may be referred to this family, although regarded as the type of a distinct group by many writers, are very long and slender, and are found to inhabit cow-dung. The larva of *Sciara militaris*, a small black insect with black wings and the lower surface of the abdomen yellow, occurs in enormous abundance in the forests of some parts of Europe, and when about to undergo their change to the pupa state collect in immense numbers and travel together in a compact body, forming a band on the ground some three or four inches broad. From the compact order in which they advance they have received the name of the ARMY-WORM (*Heerwurm*), and their trains have been observed as much as twelve feet long.

FAMILY V.—CECIDOMYIDÆ.

The Cecidomyidæ, or Gall Midges, constitute the last family of Gnat-like Diptera, and are indeed the most frail and delicate of all. They have a slender and elongated form; very long, necklace-like antennæ, composed of not less than thirteen joints, but usually of many more, in some cases as many as thirty-six, and each joint bears a circlet of short hairs; very long, slender legs, of which the tibiæ are not armed with spines, and the first joint of the tarsi is minute; and wings with very few simple veins. The eyes are lunate or notched in front towards the insertion of the antennæ. There are no ocelli; and the palpi are four-jointed and of moderate length. The females usually have a long ovipositor.

The larvæ of these elegant little insects feed upon various species of plants, generally in gall-like excrescences or distortions of the parts inhabited by them, and the different species attack different parts of the plants they infest; and in all these respects, as Professor Westwood suggests, as well as in their generally minute size and comparatively veinless wings, these insects present a striking analogy to the true Hymenopterous Gall Flies. The larvæ, which are of a stouter and more ovate form than in the preceding families, live within the part of the plant which furnishes their nourishment, which may be the young shoots, the leaves, or even the flowers, and the part thus attacked either swells into a regular gall, or becomes distorted in various ways. The number of species is very considerable, about 100 being recorded as inhabiting Europe. Many of them, by attacking useful plants, frequently do much mischief. Among these may be mentioned especially the Hessian Fly (*Cecidomyia destructor*), which has done so much damage to the grain-crops in the United States of America, and received its vernacular name from a belief that it was introduced into the States with the baggage brought by Hessian troops in the pay of the English Government about the year 1776, for which, however, there appears to be no foundation. This redoubtable fly averages rather more than an eighth of an inch in length, and is of a black colour, with some parts, such as the under surface of the abdomen, red. The female has a well-developed ovipositor. The flies begin to make their appearance in April, and continue emerging for four or five weeks. After pairing, the female sets to work to deposit her eggs, which number from 80 to 100, placing them singly, or two or three together, upon the leaves of the wheat-plants. The larvæ are soon hatched out, when they make their way down the leaf and take up their abode within its sheath. Eight or nine larvæ may be found associated in this situation, and their effect upon the plant is to weaken the haulm, so that in the first place the ear is not so well nourished as it should be; and in the second, when the ear is filled out the haulm is not able to bear its weight, but easily gives way under the pressure of the winds. These formidable larvæ seem to a certain extent to combine the characters of the ordinary larva of the Nemocera with those of the maggots of flies. They are virtually headless, but have their stigmata placed upon the sides of the segments of the body. This character is common to the rest of the larvæ of the family, in many species of which we also find another approach to the Athericerous Flies, namely, that they do not cast the larva-skin before passing to the pupa state. Hence the pupæ of the Hessian Fly are known as the "flax-seed state" of the insect. The perfect insects of the first brood emerge about the end of August, and these deposit their eggs



A, LARVÆ OF WHEAT MIDGE (*Cecidomyia tritici*) IN FLOWER OF WHEAT; B, LARVA ATTACHED TO GRAIN OF WHEAT; C, LARVA; D, PERFECT INSECT.

upon young plants of winter wheat. The larvæ arrive at maturity and change to the pupa before winter, which season they pass in the latter state. The Hessian Fly has made its appearance of late years in Posen and other parts of Germany.

The Wheat Midge (*Cecidomyia tritici*) is an enemy of the wheat crops in this country, and sometimes does much damage. This little plague, however, attacks a very different part of the plant from the Hessian Fly, the female, by means of her long ovipositor, introducing her eggs into the heart of the blossom, sometimes to the number of twenty together. The larvæ, which are of a yellow or orange colour, are known by the name of the "Red Maggot," and seem to attack the central organs of the flower, injuring them so that the seeds are unable to arrive at their full development. It was formerly supposed that they fed upon the pollen, but this does not appear to be the case. When full grown the larvæ go down to the ground, where they undergo their change to the pupa state. The perfect insect, which is about a tenth of an inch long, is of a yellow or orange colour, with black eyes. A second Wheat Midge is recorded as occurring in Britain under the name of *Lasioptera obfuscata.* The perfect insect is of a black colour; but the larvæ and pupa are exactly like those of *C. tritici*, and the habits of the two insects are identical.

CECIDOMYID WITH VIVIPAROUS LARVA.
A, Adult Insect; B, B, Pupæ; C, Larva, showing young larvæ at *a a*.

Of the actual galls produced by these insects the most striking form, and one of the best known, is that formed upon several species of willow. The fly attacks the terminal shoots, which are then stunted in their development, and are so changed in character as to make a flower-like body, compared to a rose by some of the older writers, who regarded the willows thus affected as a peculiar species, which they denominated the rose-willow. The insect producing this gall was even described under the name of *Cecidomyia rosaria.* A somewhat similar gall is produced by *Cecidomyia cratægi* and *circumdata* upon the hawthorn. Another species (*C. veronicæ*) lives in hairy, gall-like bodies on the germander speedwell. *C. salicis* forms woody galls on the twigs of willows, and *C. bursaria* resides in pyramidal hairy galls on the leaves of the common ground-ivy.

In 1860 a remarkable circumstance in the history of the Cecidomyidæ was discovered by a Russian naturalist, Dr. Nicolas Wagner, at that time Professor in the University of Kasan. He found that certain Cecidomyian larvæ living under the bark of trees develop within them organs analogous or homologous with ovaries, in the chambers of which young larvæ are produced, and these, after remaining for a time free in the general cavity of the parent larvæ, living and increasing at its expense, at last break out of it, leaving nothing but the empty skin. These young larvæ then produce other larvæ in the same curious fashion, and one generation succeeds another throughout the autumn, winter, and spring. In the summer the last generation undergoes a change to the pupa state, and from the pupa perfect males and females emerge; the latter, after impregnation, deposit a small number of eggs in the bark of trees, the larvæ produced from which commence a fresh series of agamic broods. These species have been referred to a distinct genus named *Miastor.*

FAMILY VI.—PSYCHODIDÆ.

This family includes only a few curious little insects very nearly allied to the preceding, and which, indeed, are often placed with the Cecidomyidæ. They are little moth-like creatures, with broad, deflexed, oval wings, and both wings and body thickly covered with hairs. In the structure of the antennæ they agree with the Cecidomyidæ, but the body and legs are shorter and stouter than in the insects of that family, and the wings are not only very broad, but have the veins, although not much branched, tolerably numerous.

The best-known species is *Psychoda phalænoides*, a common British insect, about a tenth of an inch long, with brownish-grey wings, which it carries divergently, as it runs about upon the surface of walls and window panes. It might easily be mistaken for a minute Moth. The larva lives in manure-heaps and among decaying vegetable matters, and is of an elongated form, with a slender, straight, cylindrical, horny tail; and the pupa has two short appendages just behind the head, in the same position as the breathing tubes of the pupa of the Gnat. Another rather larger British species (*P. sexpunctata*) has the wings rather elegantly marked with dark brown clouds or bands, and with black marginal spots.

FAMILY VII.—BIBIONIDÆ.

This last family of the Nemocerous Diptera includes a number of fly-like species; in fact, they are the division "Musciformia" of some writers. They have the body and legs considerably shorter and stouter than the species of the other families; the antennæ short, seldom longer than the head, but composed of from eight to twelve joints; the wings large, with abundance of veins, but with few closed cells. The palpi are generally four-jointed; the eyes are rounded, and in the males generally occupy nearly the whole surface of the head; and in most of them there are three ocelli.

BIBIO MARCI (MALE).

The typical Bibionidæ, including the genus *Bibio* and its immediate allies, are sometimes called "Garden Flies;" they are usually black and hairy, but often with some parts of a lighter colour, especially on the limbs; and they are commonly met with on flowers in fields and gardens, particularly in the spring and early summer. The females frequently differ in colour from the males. Thus in *Bibio hortulanus*, a common British species, the male is black, clothed with whitish hairs; while the female is reddish-yellow, with the head, scutellum, and legs alone black, and the wings in the two sexes differ in coloration. In another abundant species (*Bibio marci*), so called from its appearing about St. Mark's Day, the male has white wings and the female brown ones. Both sexes of this species are black, and clothed with black hairs. These insects fly heavily, and are sluggish in their general movements.

The females lay their eggs in the ground or in manure-heaps, and the larvæ feed either upon decomposing animal and vegetable matter, or, in some cases, upon the roots of plants, which they are said occasionally to injure considerably. These larvæ are cylindrical worms with ten stigmata along each side; they are furnished with numerous short hairs, which appear to assist them in progression. The minute larvæ of the species of *Scatopse* live in excrements. When full grown, the larvæ of the ordinary Bibionidæ make smooth oval cells in the ground, not far from the surface, and there in the spring they change to the pupa state, in which the insect remains for about a fortnight and then comes forth, the females preceding the males by about a week. The pupa is naked.

In the genus *Simulium*, which may be referred to this family, although separated from it by some entomologists, all the parts of the mouth are fully developed, as in the Gnats, although the proboscis is much shorter, and the insects are able to inflict very severe wounds with these natural weapons. Among the Mosquitoes of South America at least one species of this genus is included; under the name of "Sand Flies" they are well-known plagues in many parts of North America. In Lapland, and other northern regions, they co-operate with the Gnats in tormenting the inhabitants, and even in this country they often bite people very severely. But the most formidable

of them would appear to be the *Columbatsch Fly* (*Simulium columbatschense*), which inhabits parts of Hungary and of the regions bordering the whole lower course of the Danube, occurring in swarms, and attacking both men and cattle so vigorously that the latter, at any rate, often succumb to the injuries inflicted by their seemingly insignificant assailants. The transformations of these insects take place in the water. The larva of the common British species (*S. reptans*) is a curious little creature of a cylindrical form, with the body rather thinner in the middle; the head is distinct, and bears a pair of short antennæ, and a pair of singular fan-shaped appendages, the office of which is perhaps respiratory; the thoracic part has a stout retractile tubercle beneath; the end of the abdomen has several curved appendages. This larva lives on the sub-aquatic stems of *Phellandrium* and *Sium*, to which it finally attaches a little cocoon, open above for the reception of the posterior part of the body of the pupa. The latter, which thus sits upright in its cradle, is otherwise naked, but has on each side of the fore part of the thorax eight very long thread-like appendages, which also may be respiratory organs. The perfect insect emerges under water.

TRIBE II.—NOTACANTHA.

Although the character from which the name of this second tribe of Diptera is derived, namely, the presence of spines upon the posterior margin of the scutellum, is not a very important one, the group itself seems to be well founded, having, as already stated, peculiarities of structure and development which would ally it on the one hand with the preceding, and on the other with the following division. It thus stands very naturally between the two groups.

The group is a very well-characterised one. The antennæ, which originate close together on the forehead, apparently consist of three joints; that is to say, the first and second joints are easily recognisable, but the remainder are united in such a manner as to represent a single large joint, which, however, is more or less distinctly ringed. In some forms the apex of the antenna bears a style or bristle. The eyes are large, and there are three ocelli. The proboscis is short, and terminated by fleshy lobes, and within it there are never more than three bristles besides the labrum; but even of these the maxillary pair are often amalgamated with the labium. The legs are simple, and the tarsi furnished with three pulvilli.

The scutellum, as already stated, is usually spinous, but the number of spines is variable; sometimes there are only two, and sometimes four, whilst in a considerable number of species the hinder margin of the scutellum shows a whole row of small spines. Other characters have been already mentioned. These insects constitute only a single family.

FAMILY VIII.—STRATIOMYIDÆ.

The Stratiomyidæ are a tolerably numerous family of flies, well represented in most parts of the world. They may be divided into two subordinate groups, easily recognisable by the number of segments visible in the abdomen.

In the Stratiomyides the abdomen exhibits only five free segments. One of the best known species of this group is the *Stratiomys chamæleon*, a large and handsome fly (*see* figure on p. 84), rather over half an inch long, and of a general brassy-black colour, clothed with tawny hairs; the scutellum is yellow, and armed with two longish spines; the broad abdomen is black, with two large yellow spots on the first segment and interrupted yellow bands crossing the others; the thighs are black, and the tibiæ and tarsi tawny. The transformations of this species are very well known. The female deposits her eggs on the under side of the leaf of some aquatic plant, usually the Water Plantain (*Alisma plantago*), arranging them so as to lie one over the other like tiles on a roof. The larvæ hatched from these eggs are elongated, widest towards the fore part, where there is a small horny head, and much narrowed towards the hinder end, at the extreme point of which the only efficient stigmata are situated, surrounded by a circlet of barbed hairs which, when spread out, enables the insects to suspend themselves at the surface of the water while they breathe. By means of these hairs, when folded in, they can even carry down with them into the water a globule of air, which then looks like a small pearl. These larvæ swim by wriggling movements in which their body is bent into an S-like form. Their food consists of minute aquatic organisms, and particles of nutritive matter, brought to the mouth by the action of a pair of hairy palpi; the mouth is also

furnished with two hooks. The pupa is formed within the mature larva skin, of which, however, it occupies only the wider anterior part, and in this natural "cigar-boat" it floats freely in the water until it arrives at maturity, when the perfect fly escapes through a slit in its protective covering. The flies are found in summer upon flowers near water, and upon the leaves of aquatic plants. The species of *Stratiomys* are numerous in Europe, and some occur in various parts of the world, but

THE METAMORPHOSES OF STRATIOMYS CHAMÆLEON.

chiefly in the northern hemisphere. Species of several allied genera also pass their preparatory states in the water.

Of the rest, some, such as *Pachygaster ater* and *Clitellaria ephippium*, live as larvæ in rotten wood, and the latter is said to deposit its eggs in the nests of *Formica fuliginosa*. The larvæ of the genus *Chrysomyia*, which includes bright metallic coloured flies of small or moderate size with an unarmed scutellum, feed upon decaying vegetable matter, and the flies frequent hot-beds; and those of the larger but equally brilliant species of *Sargus* have the same habits, and are to be found in manure and garden mould. The larva of *Sargus cuprarius* is said to attack turnips.

The second group of the family, which may be named Xylophagides, is characterised by its species having seven or eight free abdominal segments. It includes a few genera, the larvæ of which, so far as is known, live in decaying wood. In Britain this group is chiefly represented by the genus *Beris*, including metallic flies of moderate size, with from four to eight spines on the

scutellum. *Beris clavipes, vallata,* and *chalybeata* are common British species. Among the exotic forms of this group are some South American species of gigantic size, some of them measuring an inch and a quarter in length.

TRIBE III.—TANYSTOMA.

This third tribe of the Diptera, which includes a considerable number of families presenting a great variety of structure and habits, is distinguished especially by the structure of the mouth, the proboscis being longer than in the preceding tribe, and sometimes very long, and the internal organs more completely developed. Thus the proboscis generally encloses a lancet-like labrum and at least three other setæ; while in one family the females, at least, present all the parts that we have described as forming the perfect Dipterous mouth. The antennæ consist of only three joints, usually furnished with a terminal bristle, which may be jointed; but in one family the bristle is wanting, and the extremity of the third joint is ringed. They differ from the Notacantha, as also from the following tribe, in the nature of the metamorphosis, the larva skin being cast when the insect passes into the pupa state. The larvæ are worm-like, but furnished with a distinct head, which bears movable claw-like organs appended to the mouth. They generally live underground.

FAMILY IX.—TABANIDÆ, OR BREEZE FLIES.

The insects of this family, which are commonly known as Breeze Flies and Gad Flies, are of a broad, robust form of body, and provided with large and strong wings. They have a broad head, hollowed behind so as to fit close to the thorax, and occupied for the most part by the compound eyes, which in the males generally meet upon the vertex, and in which the upper or middle facets are larger than the rest. They usually have three distinct ocelli. The antennæ are really or apparently three-jointed, but the third joint, which is destitute of a bristle at its apex, and is frequently deeply notched on one side, is usually ringed, either at the apex or throughout. The proboscis is long in the females, shorter in the males, and in the former it encloses the full number of bristles, two of which are deficient in the males. The abdomen is broad, and consists of eight segments; the tarsi have three pulvilli; and the wings have a complete central cell, from which three veins run to the hinder margin.

The Tabanidæ are among the finest and most powerful of the Diptera, and the females make use of the formidable apparatus of lancets with which they are endowed for the purpose of sucking the blood of man and animals. They fly about in the sunshine with a buzzing noise, from which the name of Breeze Flies is said to be derived, and alight quite imperceptibly upon their intended victims. Their bite is exceedingly painful, and their attacks are much dreaded by cattle. The males pass their time more quietly, and are usually found resting upon the stems of trees. Some 500 or 600 species are known from all parts of the world. Many of them are remarkable for the beautiful iridescent colours displayed by their compound eyes.

The preparatory states are passed in the ground, the larvæ, which have a distinct head and consist of twelve segments, feeding, it is believed, upon the roots of grasses and other plants. About the month of May the larva is full grown; it then sheds its skin and becomes converted into a free pupa, having fringes of hairs on the abdominal segments, and a circlet of bristles near the end of the abdomen—structures which are of use to the pupa in making its way out of the ground when about to give birth to the perfect insect. This takes place in the summer, and at this season the Breeze Flies are often a source of great discomfort to both man and beast in many parts of the country. The female of the large Ox Breeze Fly lays some four or five hundred eggs upon grass stems, and the larvæ are hatched from these in ten or twelve days.

In this country we have several species which are referred to three genera, but most of them belong to the typical genus *Tabanus*. The largest of them, and, indeed, one of the largest known species, is the Ox Breeze Fly (*T. bovinus*, see figure on p. 86, and Pl. 62, D), of which the females measure nearly an inch in length; but it is not very abundant in Britain. *Tabanus autumnalis*, one of the commonest species, measures from two-thirds to three-quarters of an inch, and is of a blackish-brown colour, with bronzed brown eyes, and the rest of the head yellowish-white, the antennæ black, the thorax marked with five grey stripes, and the abdomen with five rows of greyish spots. The wings are grey, with a tawny tinge at the base and along the front margin; the halteres are brown with

yellow knobs, and the tibiæ yellow with black tips. In another well-known British *Tabanus* (*T. tropicus*) the eyes are of a brassy-green colour, with three purple bands; and in another smaller species, the GOLDEN-EYE (*Chrysops cæcutiens*), which is also widely distributed, these organs are of a beautiful golden-green colour, with five spots and the hinder border purple. The most abundant of all the British species is the CLEGG (*Hæmatopota pluvialis*), which is particularly common in low, damp situations, where it is a great plague. This is a dingy, grey-looking insect, with a

THE METAMORPHOSES OF TABANUS BOVINUS.

greyish-brown body, and mottled-grey wings. It is distinguished generically from the *Tabani*, which have antennæ of three joints, with the last deeply notched at the side, and ringed near the tip, by the possession of slender antennæ, in which the third joint is rather long, and followed by three short but apparently distinct joints; it is also destitute of ocelli. The generic name, which may be taken to signify "blood-drinker," is well conferred upon it. In the genus *Pangonia*, several species of which inhabit the continent of Europe, especially in the south, the proboscis is very variable in length, sometimes being more than twice as long as the body.

FAMILY X.—ASILIDÆ.

In these insects, which, from their habits, might very well be called "Hawk Flies," the general form of the body is elongated, and more or less cylindrical, and the head is more rounded and separated

from the thorax, and less occupied by the eyes than in the Tabanidæ. The head is bearded at the sides and beneath. The antennæ show three joints, of which the third is usually simple and long, and terminated by a bristle or style of two joints. The proboscis is generally of moderate length, but strong, horny, and sharp-pointed; it encloses three bristles (besides the labrum), and the upper one, which probably represents the united mandibles, is very strong. The abdomen is elongated, pointed, and generally composed of eight segments; the tarsi have two pulvilli; the wings generally show two complete cells on the disc.

In their habits the Asilidæ are among the most predaceous of their order; but instead of feasting upon the blood of the higher animals, they content themselves with sucking out the fluids of other insects, which they pounce down upon with hawk-like violence, often lying in wait for a passing prey upon fences, walls, and the twigs of trees. Their prey consists largely of Dipterous flies, but they also freely attack insects of other orders; even the hard coats of Beetles and Hymenoptera are not a sufficient defence from the formidable lancets of the Asilidæ, and the larger species of the family are even said to attack and destroy Dragon Flies.

The larvæ are long, depressed, footless grubs, with a scaly head; they live underground, feeding upon the roots of plants and decaying vegetable matter, or in rotten wood; they undergo their transformations in the same situations, and the pupæ have the head armed with spines, and the segments of the abdomen with rows of spinules, which assist the insect in making its way out when the time for its final change has come.

The family probably includes about the same number of species as the preceding one, and they are distributed over the whole surface of the globe. They are generally robust, hairy insects, with strong limbs, and they hold their prey with their fore legs while engaged in sucking out its juices. Many of them, and especially the exotic forms belonging to the genus *Mydas*, inhabiting the tropical parts of America, are of large size; *Mydas giganteus*, a deep black Brazilian species, often measures an inch and three-quarters in length. Even of our European and British species, one of the commonest, namely, the *Asilus crabroniformis*, attains a length of an inch. It is of a tawny yellow colour, with four brown stripes on the thorax, and the basal part of the abdomen black. This insect is said sometimes to attack cattle and other animals. *Leptogaster cylindricus*, a British species, is remarkable for its slender cylindrical abdomen, which is considerably longer than the wings, and in the female is slightly enlarged at the end. It has in consequence some resemblance to the *Tipulæ*, and, like those insects, frequents meadows during the summer.

ASILUS CRABONIFORMIS.

FAMILY XI.—THEREVIDÆ.

The Therevidæ form a small family of insects, similar to the Asilidæ in the general form of the body, but distinguishable at once by the structure of the proboscis, which is short, not very prominent, and terminated by fleshy lips. The bristles enclosed in it are also much feebler than in the Asilidæ. The antennæ are short, of three joints, and the third joint has a thin style at its extremity; the ocelli are distinct; the abdomen consists of eight segments; the legs are thin, and the tarsi have two pulvilli; and the wings have one complete discoidal cell. The larvæ live in vegetable mould, or in rotten wood, and are exceedingly long and slender, having a small head with a pair of short antennæ, and apparently consisting of about twenty segments, owing to a seeming division of the middle segments. The pupa has the fore part armed with spines, like that of *Asilus*. The species, which are generally of moderate size, are found in most parts of the world, and agree in their general habits with the Asilidæ, although they are more sluggish in their movements, and cannot display so much ferocity in the pursuit of prey. They feed chiefly upon other Diptera, for which they lie in wait in various situations, sometimes on the ground in sandy places, but more frequently upon the leaves and branches of shrubs and trees, and on flowers. The commonest British species is *Thereva plebeia*, an insect rather more than one-third of an

inch long, black, clothed with tawny hairs, with the wings greyish, tawny at the base and along the front margin, the hinder margins of the abdominal segments gilded, and the legs tawny, with the thighs black.

FAMILY XII.—EMPIDÆ.

This is another family of Asiliform Flies, having an elongated body, a pointed abdomen, and a horny proboscis. The head is globular, and the eyes of considerable size, meeting in the middle in the males; the crown of the head is not excavated as in the Asilidæ; the ocelli are distinct; and the antennæ are of three joints, with a long and often jointed style or bristle at the apex. The proboscis, which is horny and destitute of terminal lips, is generally of moderate length, and placed perpendicularly under the head; sometimes, however, it is very long, and is then folded beneath the breast. It contains three bristles, which are much finer than in the Asilidæ. The wings have a single complete cell on the disc. In their transformations the Empidæ resemble the species of the preceding families.

Although much smaller than the Asilidæ, the Empidæ are equally predaceous in their habits, feeding voraciously upon insects of various kinds, but especially upon other Dipterous flies. They may constantly be found flying or running about, carrying with them, transfixed by the bristles of the mouth, insects quite as large as themselves; and in some, forming the genus *Hemerodromia* and its allies, the fore legs are even converted into prehensile organs, the coxæ being as long as the thighs, and the thighs thickened and spinous beneath.

These, and many other species, all of small size, pursue their prey by running rather than on the wing. They are found upon the leaves of shrubs and herbage, and their quickness of foot is expressed in several of the generic names applied to them, such as *Tachydromia* and *Ocydromia.* These insects are characterised by the structure of the antennæ, in which the first joint is so small as to be lost sight of; so that the organs apparently consist of only two joints, with a long bristle either at the apex or on the back of the apical joint.

The number of species in this family is very great, but they are chiefly confined to the temperate or colder regions of the earth. They are very numerous in Europe. In default of insect prey, or to vary their diet, they visit flowers and suck up the honey. Many species frequent the neighbourhood of water, and some, such as the *Hilaræ,* assemble in great swarms over the surface of a stream and engage in most complicated aërial dances.

The largest species of the family belong to the typical genus *Empis,* the female of one of the best known British forms (*Empis tessellata*) attaining a length of nearly half an inch. This insect is of an ash-grey colour, with three black stripes on the thorax, and the abdomen showing a sort of tessellated pattern. It is common in spring. When paired, the females of this and of many other of the larger species of the family are always found to be busily engaged in sucking out the juices of some other insect. It seems probable that the male seizes the opportunity of his intended partner being thus occupied to make his advances; if her mouth was free he would in all likelihood himself fall a sacrifice to her voracity.

FAMILY XIII.—ACROCERIDÆ.

A few very curious flies constitute this family, the true position of which has often been a puzzle to entomologists. They seem, however, to be most nearly related to the Humble-bee Flies, which form the next family. They have the thorax and abdomen much inflated, the thorax especially being much swelled above, and the head very small and globular, and placed very low down upon the front of the thorax, so that it is more or less concealed when the insect is looked at from above. The eyes are comparatively large, forming the greater part of the surface of the head, but there are usually three distinct ocelli. The three-jointed antennæ are very small; the proboscis either long and thin, and bent under the body, or entirely wanting; the legs short and weak, with three pulvilli to the tarsi; and the halteres concealed beneath large, arched scales. The abdomen has only six segments.

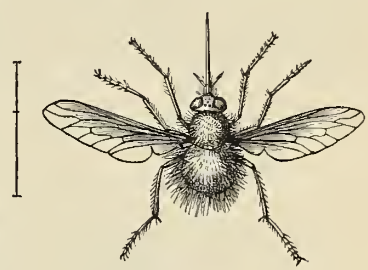
The known species of this family are not numerous. Those possessing a long proboscis are chiefly exotic, but in them this organ is usually longer than the body. Thus *Lasia flavitarsis,* a Brazilian species of a steel-blue colour, with the scutellum and base of the abdomen violet and

the tarsi yellow, measures about half an inch long, and has a proboscis three-quarters of an inch in length. These long-trunked species feed upon the juices of flowers; the labrum is very short, and the three bristles enclosed in the proboscis are thin. Most of the European species are destitute of a proboscis, and apparently take no food after arriving at the perfect state. They are not abundant, and are feeble and slow in their movements, generally passing their time upon leaves and flowers, or sitting upon the trunks and branches of trees, about which they often fly in the bright sunshine. The females deposit their eggs, which are very numerous and black, upon the dried twigs of trees. Scarcely anything is known of their preparatory states, but it is supposed that the larvæ are parasitic in their habits.

FAMILY XIV.—BOMBYLIIDÆ.

The Humble Bee Flies, which are the typical forms of this family, agree, to some extent, with the preceding insects in general form, although they have not the thorax and abdomen so much inflated; but the group includes a number of species which show no such structure of the body. They have rather a small head, with large eyes which usually meet in the male, and three ocelli; the antennæ are of moderate length, of three joints, and well extended in front of the head; the proboscis is long and projected in front of the head, and the bristles contained in it are very delicate; the abdomen consists of six or seven segments; the legs are long and thin, and the tarsi have three pulvilli, of which the middle one is often hair-like; the wings diverge on each side of the body, and there is no scale covering the halteres. The transformations of these insects are somewhat imperfectly known, but the larvæ of many of them are undoubtedly parasitic upon other insects, some attacking the caterpillars of Lepidoptera, while others live in the nests of different species of solitary Bees.

The great majority of the species of the family are exotic, and they occur in all parts of the world. The most extraordinary development of the proboscis occurs in a species from the Cape of Good Hope, *Nemestrina longirostris*, which measures about two-thirds of an inch in length, and has a proboscis nearly three inches long, which it employs in sucking the nectar from the long-tubed flowers of the *gladioli*, &c. The sweet juices of flowers, in fact, constitute the general food of the insects of this family, and in search of it they sweep from flower to flower with a rapidity that shows great strength of wing; and while engaged in probing the recesses of the flowers with their long trunks, they usually hover motionless in the air, like minute Humming-birds. They generally show no brilliancy of colour, shades of brown and black being the prevailing tints. The typical *Bombylii*, which are stout-bodied insects densely clothed with hairs, somewhat like little Humble Bees, are represented in Britain by about four species, out of over a hundred which exist in other parts of the world. Two of them (*Bombylius major* and *B. medius*), which measure a little under half an inch in length, are common in gardens and woods, and on sandy heaths, during the spring and summer. They are both black, and clothed with tawny or yellowish hairs, but the former has transparent wings, with a dark brown stripe starting from the base and running along the anterior margin nearly to the tip of the wing, while the second has greyish wings, with a yellowish-brown band running from the base along the fore border, and beneath it a series of brown spots. In the genus *Anthrax*, species of which are met with in dry places flying over the surface of the ground in the hot sunshine, and resting from time to time, with their wings widely expanded, upon a stone or other projection, the base and fore margin of the wings are usually black, the dark and light parts of the wings generally occupying nearly equal spaces.



BOMBYLIUS MAJOR.

FAMILY XV.—LEPTIDÆ.

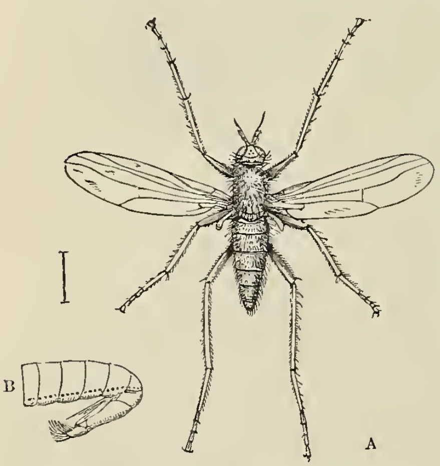
The Leptidæ form a very small family allied to the preceding, but having the antennæ very short, composed of three joints, of which the last is bent down, and bears a bristle either at its apex or near its base. The proboscis also differs, being short and thick, and terminating in a pair of fleshy lobes. There are three bristles in the proboscis, and the palpi are long and

prominent, consisting of a short basal and long second joint. In general form the insects are rather slender, with a long abdomen; the legs are slender, with three pulvilli on the tarsi; the wings have one complete cell on the disc.

These insects are generally of moderate size, and frequently have the wings spotted. They are found during the summer in meadows, about hedges, and in woods. They are sluggish in their habits, and the larger species are commonly found sitting on the trunks of trees, always with their heads downwards. They sometimes prey upon other insects. The larvæ live in the ground, in sand, manure, and decayed wood; and that of one species (*Leptis vermileo*) is described as making small conical pitfalls in the sand, for the purpose of entrapping small insects, after the fashion of the Ant-lion. The habits of another species, (*Atherix ibis*), not uncommon in Britain, are still more curious. The fly, which is about a third of an inch long, is of an ash-grey colour, with transparent wings thickly covered with more or less confluent brown spots. The females are gregarious, and attach their eggs in large pear-shaped clusters to boughs overhanging streams of water. The cluster is formed by the contributions of numerous females, which remain on the spot and die there, and when the larvæ are hatched they fall into the water, which is their future residence.

FAMILY XVI.—DOLICHOPODIDÆ.

This is a numerous family of small flies generally adorned with bright metallic colours, which in some respects seem to form a passage to the next tribe. They have three-jointed antennæ, short or of moderate length, but prominent, and the third joint, which is either oval or pointed, has a bristle springing either from its extremity or its back. The proboscis is short, thick, and fleshy, and contains only one bristle, the maxillæ being united with the labrum, although their palpi, which consist only of a single joint, are of considerable size. The labrum is large and horny. The head is of moderate size; the eyes usually separate in both sexes; the ocelli distinct; the legs long and thin, but often showing very curious developments of certain parts, especially the tarsi, which have three pulvilli, of which the middle one is smaller than the others; and the wings have only five longitudinal veins, with a cross vein uniting the fourth and fifth. The structure of the abdomen in the males is very peculiar. It is composed of six segments, and its apex is bent forward, and furnished with an extraordinary variety of copulatory appendages. The larvæ are long, slender, and cylindrical, and live in the ground or under the decaying bark of trees; they have the last segment thickened, and furnished with two tubercles above, each of which bears a stigma. The pupa is found in the same situations as the larva, and is free, with two curved horns on the thoracic region and rows of bristles upon the segments of the abdomen.



A, DOLICHOPUS DISCIFER. B, SIDE VIEW OF THE EXTREMITY OF THE ABDOMEN OF THE MALE.

In their habits, notwithstanding the imperfection of their mouths, the Dolichopodidæ are all predaceous; in this respect resembling some of the Empidæ, with which they would seem to have considerable relationship. They are found running about, backward, forward, and sideways, upon the leaves of plants and trees, from which they are said to be fond of licking the honey-dew; and they also frequent the trunks of trees, walls, palings, &c.; but many of them haunt the neighbourhood of water, and seize insects, and even small worms and mollusca, when they come to the shore. Some of them actually venture upon the water in pursuit of prey, running freely upon the surface, after the manner of those curious long-legged Bugs (*Gerris*) whose movements must be familiar to every one. One genus has received the name of *Hydrophorus* from this circumstance, and they not only frequent the surface of lakes and ponds, but even venture on the sea. These and some others have the fore legs fitted to act as raptorial organs. The prey, when seized, is readily admitted into the gaping orifice at the extremity of the short proboscis, and held fast there while its fluids are being sucked out. Many of the species live in the vicinity of the sea-coast.

The species are exceedingly numerous, and they are found in most parts of the world. Over 200 are recorded as inhabiting Europe, and a large proportion of these occur in Britain. A great many have also been described as inhabitants of the United States, but the known species from tropical and southern regions are comparatively few, so that as far as present knowledge goes the family would seem to abound particularly in the temperate and colder parts of the northern hemisphere. Many species are found high up on mountains.

FAMILY XVII.—PLATYPEZIDÆ.

The Platypezidæ are a very small family of minute Diptera, nearly related to the Dolichopodidæ, but differing from them in the flattened form of the body, the hemispherical shape of the head, which in the males is almost entirely occupied by the eyes, the shortness of the legs, of which the posterior pair are stout, and the presence of six instead of five longitudinal veins in the wings. The number of species is small, and very few are recorded from beyond the European region. Most of the genera are represented in Britain.

The perfect insects, most of which are under one-sixth of an inch in length, are active in their habits, and are generally found in woods and about hedges, although some of them prefer the herbage of marshy localities. Their larvæ live in fungi, and are broad and rather flattened, with stiff bristles along their margins. These insects, like the preceding, seem to lead towards the next tribe.

FAMILY XVIII.—SCENOPINIDÆ.

A few very small flies, which seem to have some affinity to the Therevidæ, have been formed into a separate family under the above name. They have short antennæ, with three joints, of which the third is the longest, blunt at the tip, and without any bristle; a very short, fleshy proboscis, terminated by broad lobes, but with only a single enclosed bristle; short legs; and wings with a complete cell on the disc. These insects also lead in the direction of the next tribe, but their long slender larvæ, which live in fungi, cast their skin on passing to the pupa state, and in other characters, such as the venation of the wings, they rather resemble the central types of the Tanystoma. *Scenopinus fenestralis*, a small fly rather more than a sixth of an inch long, receives its specific name from its being common on windows, especially those of stables; it is also found on the leaves of plants and about walls. It is black, with reddish tawny legs. Another common species in similar situations (*S. fasciatus*) is entirely black except the tarsi, which are reddish.

TRIBE IV.—ATHERICERA.

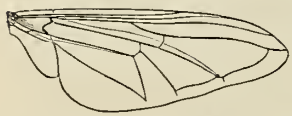
As already indicated, some families of the preceding tribe show an evident transition towards the present one, but in all cases the character of the metamorphosis serves to turn the scale. In all the Tanystoma the larva skin is cast when the insect passes into the pupa state; in all the Athericera the transformation takes place within the skin of the larva, which hardens into an oval case, serving efficiently as a protection to the helpless inmate. The antennæ throughout the tribe consist of only two or three joints, of which the third is never ringed, but generally furnished with a style or bristle, which may spring either from its extremity or from its back. The proboscis is sometimes quite rudimentary, but is generally a more or less fleshy or membranous organ, with very distinct terminal lobes; it is always elbowed at a short distance from its base, and in most cases can be retracted within the cavity of the mouth, which is situated on the lower surface of the head. The palpi, which consist of a single joint, are attached to the sides of the proboscis a little above the bend, so that when the proboscis is withdrawn they are entirely concealed. In one family of the tribe the proboscis encloses three lancets besides the labrum; in the remainder only one.

The larvæ are soft, fleshy, footless grubs, distinctly segmented, narrowed, and usually pointed in front, but without anything that can be distinguished as a head. The mouth is furnished with one or two hook-like organs, and usually with fleshy lobes, and with a kind of tongue. The posterior end of the body generally terminates bluntly, and is in many cases cut off quite flat. Upon the surface of the last segment we find a pair of stigmata, which are the sole breathing apertures of the larva. In general terms, we may say that most of the larvæ of this tribe are *maggots*. A few aquatic larvæ are provided with breathing tubes.

On passing to the pupa state the larva skin contracts more or less, and generally becomes much shorter, at the same time that the two ends of the body become equally rounded, and thus the whole assumes an oval form. Even the traces of the segments become much fainter, or almost unrecognisable; but in many the line marking off the lid, which will be thrown off for the escape of the perfect insect, is to be seen distinctly towards the anterior end of the case. At first the enclosed insect detaches itself from the larva skin, and thus forms a soft, more or less pulpy, shapeless mass, on the surface of which, by degrees, the rudiments of the parts of the perfect insect make their appearance. When mature the fly throws off the lid of its case by the action of the head, which commonly acquires a sort of temporary bladder-like inflation for this purpose (see figure on p. 72).

FAMILY XIX.—SYRPHIDÆ.

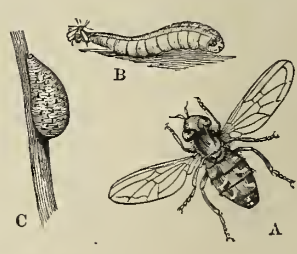
Although the insects of this tribe present an almost infinite variety of structure, they are usually divided only into two great families, which are very distinctly characterised. The Syrphidæ form a family of tolerably uniform character, and it is in the second of the two groups that the great variety is displayed, although the whole are united by certain peculiarities, and the subordinate types melt into one another.



WING OF SYRPHUS. (*Enlarged.*)

The Syrphidæ may always be recognised by a very obvious though apparently unimportant character, namely, the presence in each wing of a peculiar false vein, intersecting the short cross vein between the third and fourth longitudinal veins. The longitudinal veins themselves do not generally reach the margin of the wing, but terminate in fine veins which unite them, and usually run parallel to the margin, cutting off a narrow border. The antennæ are three-jointed, with an apical or dorsal bristle, which is in some genera beautifully feathered; the eyes are large, meeting in the males; the ocelli are three in number; the proboscis usually short, with fleshy end-lobes, and enclosing three bristles besides the labrum, the maxillæ being free; the palpi are formed of a single joint, and are not prominent; the abdomen consists of five segments, and is flattened, and occupied, to a great extent, by air sacs; and the tarsi have two pulvilli.

This family consists for the most part of elegant, brightly-coloured flies, remarkable for their rapid flight, and for the ease with which they hover in the air over flowers. During flight many of them produce a loud piping or buzzing sound. They are of moderate or considerable size, and occur abundantly in all parts of the world. The surface is sometimes naked and shining, sometimes hairy, and in the latter case the insects have a bee-like appearance. They are constantly seen about flowers, upon the juices of which they feed, and are particularly partial to the flowers of the Compositæ. Notwithstanding the uniformity of the characters and habits of the perfect insects, the larvæ exhibit a considerable diversity in both respects. Some of them are aquatic in their habits; but the majority live out of the water, some feeding upon the roots and bulbs of plants, others living in decaying wood, in mud, and even in sewers, others again being parasitic in the cells of Wasps and Humble Bees, while a considerable number crawl over the leaves and shoots of plants, and co-operate with the larvæ of the Neuropterous Hemerobiidæ in the destruction of Aphides.



SYRPHUS PYRASTRI (A), LARVA (B), AND PUPA (C).

The last-mentioned habit is displayed by the larvæ of the typical genus *Syrphus* and its allies. These are the prettily banded flies which may be seen everywhere in gardens and in the open country throughout the summer, often hovering motionless for a considerable time over some object, such as a flower, but darting off with remarkable rapidity when disturbed, and often returning again and again to the same spot. We have some thirty British species of the genus *Syrphus*, and most of them are abundant and widely distributed. One of the commonest is the *Syrphus pyrastri*, an insect about half an inch long, of a blue-black colour, with a stripe on each side of the thorax and the scutellum tawny, and three whitish or yellowish bands, interrupted in the middle, upon the abdomen. The wings, as is usual in these flies, are colourless and transparent; the halteres are yellowish, and the legs are yellowish, with the thighs more or less black. By many people these harmless flies are mistaken for wasps, and some of the allied species are particularly wasp-like.

Their larvæ, which are footless grubs, generally much wrinkled across, live upon the leaves and twigs of plants which are infested by Aphides, in pursuit of which they crawl along upon their flattened under surface in a manner which somewhat reminds one of the movements of a common slug. They are narrowed in front, and have no distinct head, but the mouth is furnished with a sort of trident with which the larvæ transfix the Aphides and suck out their fluids. When full grown the change to the pupa takes place within the larva skin, which remains attached to a leaf or twig, and hardens in the usual way. As the parent flies always lay their eggs singly in the midst of colonies of Aphides, the larva when hatched has of course an abundant supply of food at its command; its growth is in consequence rapid, and there are several broods of the flies in the course of the summer. By their destruction of Aphides they must be regarded as conferring an important benefit upon the farmer and gardener.

The *Volucellæ* (see Pl. 62, F), which are nearly related to the *Syrphi*, but are of a stouter form of body, and less gaily coloured, reside in the larva state parasitically in the nests of Wasps and Humble Bees, and sometimes they mimic the appearance of the insects in whose dwellings they are unbidden guests in a most remarkable manner. This is remarkably the case with a common British species (*Volucella bombylans*), which infests the nests of Humble Bees; it is black and hairy, precisely resembling a small Humble Bee, about half an inch long, and, curiously enough, it even varies in the colour of the hair on certain parts of the body, and this very much as in different species of Bees. The larva has the body much wrinkled, and along each side a double row of short spines, while four or six longer spines radiate from the broad and rounded hinder extremity; and below there are six pairs of tubercles, each with three claws, which may be regarded as prolegs. These larvæ feed upon those of the *Bombi* and Wasps whose nests they frequent.

ERISTALIS TENAX AND ITS RAT-TAILED LARVA.

A considerable number of the species, however, appear to feed on vegetable matters, either fresh or in state of decay; the larvæ of several species feed on the bulbs of plants (some on those of *Narcissus*); others, forming several genera, live among rotten wood. Of this number are many species of the genus *Eristalis*, but that group includes one species with an aquatic larva. It is a stout, pitchy black, hairy fly, over half an inch long, with the scutellum, the hind borders of the abdominal segments, and a triangular spot on each side of the base of the abdomen tawny; it is met with abundantly everywhere in gardens and fields. The larva is a most singular creature, having a somewhat ovate segmented body, furnished beneath with seven pairs of tubercles armed with hooks, and terminated posteriorly with a long tail composed of two segments, one of which slides within the other after the fashion of the joints of a telescope. This tail enables the larva to communicate with the air for respiratory purposes when it is lying snugly concealed in the mud at the bottom of some piece of stagnant water, which is the regular habit of the insect in this stage. When full grown the larva quits the water and buries itself in the ground, where the pupa is formed in the usual way within the larva skin. These larvæ are commonly known as "rat-tailed larvæ." Their skins are exceedingly tough, and in allusion to this the species is named *Eristalis tenax*. *Helophilus pendulus*, a nearly allied species, has a similar larva, with similar habits.

FAMILY XX.—MUSCIDÆ.

The remainder of the Athericera are generally regarded as forming a single great family, of which the genus containing the common House Fly (*Musca domestica*) may be taken as the type. The members of this family are, as already stated, very variable in their character. They have three-jointed antennæ, and these, except in one genus (*Conops*) which shows a strong relationship in other respects to the Syrphidæ, are short, have the third joint usually the largest and furnished with a bristle springing from its back, and are commonly bent down in front of the face. The proboscis has fleshy terminal lobes, and encloses only a single bristle besides the labrum; the palpi generally project

and consist of one joint; the wings show no trace of the false vein which characterizes the Syrphidæ; the tarsi have two pulvilli; and the abdomen consists of five segments. There is no doubt that this is not only the most varied but also the most extensive family of the Diptera. It includes some thousands of species distributed over all parts of the world, and the species are probably nearly as numerous as those of all other families of the order taken together. Of such a multitude it is scarcely possible to make any general statements, but it may be remarked that of many species the individuals are excessively numerous, and that in consequence their influence for good or for evil is very great. The larvæ are for the most part of the kind known in common parlance as "maggots," and they present a great variety of habits. Many are parasitic not only in other insects, but even in vertebrate animals; others reside in living plants, and feed upon their substance; others again seek dead and decomposing animal and vegetable matter and even the excrements of animals; whilst a few are found in water. Of the latter the most remarkable are the *Ephydræ*, several of which occcur in salt water, and even in the condensed brine of salt works. These have a long breathing tube something after the fashion of the rat-tailed larva of *Eristalis tenax*. The number of species whose habits render them directly injurious to man and his possessions is not very great when compared with that of those whose action in the economy of nature must be regarded as beneficial, such as the parasites upon the larvæ of injurious insects and the consumers of carrion and other impurities.

CONOPS FLAVIPES. (*Twice natural size*).

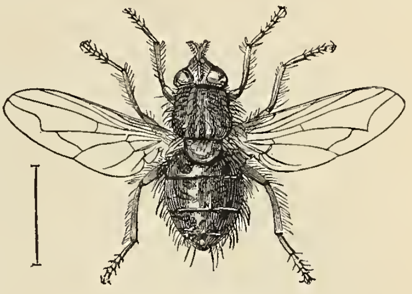
In the exceptional genus *Conops*, already referred to, the antennæ spring from a projection of the forehead, and are prominent and longer than the head; their first joint is short, the second very long and thickened towards the apex, and the third short, stout, and conical, with a short, jointed style at the apex. They are handsome flies, generally black, banded with yellow, and frequent flowers after the manner of the Syrphidæ. Their larvæ are parasitic in Bees, Wasps, and Grasshoppers.

Another group of parasitic Muscidæ consists of the great genus *Tachina* and its allies, forming the sub-family TACHINARIÆ. These have the scales behind the base of the wings very large, entirely concealing the halteres, and the bristles projecting from the third joint of the antennæ either entirely naked, or hairy or plumose only at the base. Of this group there are several hundred species in Europe alone, and they are abundant in all parts of the world. In the larva state they are parasitic upon other insects of various orders, chiefly, however, the caterpillars of the Lepidoptera, although Beetles, Field Bugs, Earwigs, Grasshoppers, and other Orthoptera, and the larvæ of Saw Flies, are commonly attacked by them, and some species live in the nests of Bees and Wasps, while others even attack Spiders. The flies themselves are generally moderately stout and rather roughly hairy. They fly with great rapidity. One of the largest and finest species, which is abundant in many parts of Europe, and not uncommon in Britain, is the *Tachina grossa* (see Pl. 62, K), which measures two-thirds of an inch in length, and is of a black colour, clothed with bristles rather than hairs, and with the head and base of the wings reddish-yellow. The antennæ in this insect are of peculiar structure; they have the second joint much longer than the third, which is broad and somewhat quadrangular.

Gymnosoma rotundata is distinguished from the rest of the group by its inflated, nearly spherical abdomen and the absence of the strong hairs which most of them possess. It is rather more than a quarter of an inch long, black, with the abdomen yellowish-red, banded and spotted with black. The larva of this insect is parasitic upon a Field Bug (*Rhaphigaster punctipennis*). In *Prosena siberita* the proboscis is very long and slender, and the bristle of the antennæ is feathered, thus indicating a transition towards the next group. Many of the exotic species are adorned with beautiful colours. One of the finest is the Australian *Rutilia splendida*, which has the upper surface adorned with golden green spots, with blue superficial reflections.

The MUSCARIÆ form a second group having the halteres concealed by the wing scales, but in them these organs are generally smaller than in the Tachinariæ, and the bristles of the antennæ are feathered or hairy to the apex. This group includes the commonest and best known species of the family, such as the Common House Fly (*Musca domestica*) and the Bluebottle (*Musca vomitoria*). The larvæ live either upon dead flesh or excrements, and the attacks of some of them upon meat

during the summer are only too familiar to housewives. The larvæ of the common Fly reside in excrements of all kinds, and consequently the insects abound especially where such substances are allowed to accumulate, as in the neighbourhood of stables, &c. The flesh-eating species are tolerably numerous, and most of them are viviparous, depositing living larvæ, which are hatched in the oviducts, upon dead animal substances of all kinds. The ovarian organs are of large size, and the female of *Sarcophaga carnaria* may produce as many as 20,000 young larvæ, and thus one cannot be surprised at the influence these seemingly insignificant animals have in the removal of carrion. The Flesh Fly (*Sarcophaga carnaria*), one of the largest of our species, is about half an inch long, black, with six greyish-white streaks upon the thorax, and four rows of square white spots upon the abdomen. Under the term Bluebottle at least two species are included, namely, *Musca vomitoria* and *M. erythrocephala.* They both have the under surface of the head red, but in the former this part is clothed with reddish and in the latter with black hairs. There are also two abundant species of so-called Greenbottle Flies (*Musca cæsar* and *M. cornicina*), remarkable for their beautiful golden-green or bluish-green colour, but distinguishable by the palpi being tawny in the former, black in the latter. There are many other species, and all have the same scavenger-like functions to perform in the economy of nature. Occasionally, however, these larvæ become directly injurious to man, by getting introduced into the stomach with food, or by attacking sores and other open wounds. In the latter way they also frequently plague domestic and other animals.



MUSCA VOMITORIA.

A fly closely resembling the common House Fly is the *Stomoxys calcitrans,* which, however, is furnished with a long, slender, projecting proboscis, by means of which it pierces the skin and sucks the blood of man and other animals. A still more formidable species is the Tsetse Fly (*Glossina morsitans*) of tropical Africa, of which such terrible accounts have been given to us by travellers in those regions. The Tsetse, which inhabits certain parts of Central Africa, bites cattle so severely as to injure them greatly, causing them to fall into a diseased state and finally die; in fact, the action of this fly is said to be so pernicious as to render the zones which it inhabits impassable barriers to man and domestic cattle.

THE TSETSE FLY.
(Three times natural size.)

An immense number of species of Muscidæ have the halteres uncovered, the wing scales being either absent or greatly reduced in size. The group formed by them has in consequence received the name of Acalypteræ. In other respects they exhibit considerable differences both of structure and habit.

The larvæ of a considerable number live in excrements, and one of the most abundant of these is a dingy yellow-looking fly, about a third of an inch long, which may be met with during the greater part of the year, flying about and alighting upon manure heaps in the fields and elsewhere. This insect is very appropriately denominated *Scatophaga stercoraria,* both generic and specific name serving to indicate the unsavoury nature of its haunts. Its eggs are deposited in dung, as moisture is necessary for their development, but in order that the young larva may not be smothered on its emergence from the egg, the latter is not wholly immersed, but is prevented from sinking by two divergent horns springing from its upper end. The perfect insect preys on other Diptera. The *Anthomyiæ,* which are exceedingly numerous, over 200 European species being recorded, are nearly related to the preceding, and, like them, deposit their eggs in excrementitious matter. Except when engaged in oviposition, however, the perfect flies generally frequent flowers, as, indeed, is expressed in their generic name. They are common frequenters of our gardens. One of the most abundant

species (*Anthomyia lardaria*), resembles the Flesh Fly in size and general appearance, having the thorax streaked and the abdomen tessellated in much the same way.

In the genus *Ephydra* and its allies the larvæ are aquatic in their habits, generally residing either in the semi-fluid green matter that is so commonly seen on the surface of stagnant water, or in the mud at the bottom of shallow pools. In general these larvæ possess respiratory tubes. Some of them, as already mentioned, live in salt water, either on the sea-coast or in the pools of salt marshes, whilst some have been found in strong brine. The perfect insects frequent the shores of the pools in which the larvæ reside, and appear to feed chiefly upon other insects. *Ochthera mantis* has the forelegs greatly developed, the coxæ long, thighs very stout, and the tibiæ curved, so as to form a raptorial limb. It is found commonly upon sandy shores.

The numerous species of the genera *Ortalis* and *Trypeta* deposit their eggs upon living plants, within the substance of which the larvæ afterwards feed, often producing gill-like excrescences. They are generally small flies, and have the wings either transparent with dark spots, or of a dark colour with transparent spots, and as they walk about they keep these organs in constant tremulous motion. They are particularly attached to the Compositæ. *Dacus oleæ*, a species of a nearly allied genus, chiefly represented in the tropics, attacks the olive. The larva feeds at first upon the leaves, but afterwards upon the pulp of the fruit, which it often seriously injures. It is known in Provence under the name of "Chiron." The genus *Chlorops* includes a number of small and delicate species, the larvæ of which reside in living plants, and are especially attached to the Gramineæ. They reside within the stems of the plants, feeding upon the interior substance, and thus prevent the formation of seed by intercepting the supply of material. In this way several of the species are exceedingly injurious to corn crops, notwithstanding their minute size, which rarely exceeds an eighth of an inch. They are generally yellow, prettily streaked on the thorax, and banded on the abdomen with black (*Chlorops lineatus* and *C. tæniopus*).

CHLOROPS TÆNIOPUS.

The PHORIDES constitute a small group which has been regarded as a distinct family by many writers. They are distinguished by having only three longitudinal veins with no cross vein in the wings, and the antennæ placed quite low down towards the mouth, and exceedingly short. The species, which are not numerous, are all of small size, and their larvæ feed upon fungi and decaying vegetable matters.

The ŒSTRIDES, forming the last sub-family of the Muscidæ, are all parasitic in the larva state, and are the "Bot Flies" only too well known to farmers. They have very short, wart-like antennæ, which are sunk into cavities of the forehead, from which nothing more than the apical bristle projects, and the proboscis is quite rudimentary. The species show three different modes of parasitism, but all devote their attention solely to mammals.

Those of the genus *Œstrus* lay their eggs upon the hides especially of cattle and deer, and the larvæ, when hatched, make their way under the skin and there take up their abode, producing large and painful swellings, with an opening at the summit, where the hinder extremity of the larva remains in communication with the air for the purpose of respiration. The best-known species is parasitic on our domestic cattle (*Œstrus* or *Hypoderma bovis*), and is particularly partial to young steers. The abdomen of the female has a sort of telescopic termination, which is instrumental in attaching the eggs to the skin of the ox. The cattle are so well aware of the danger attending the presence of the insect, that as soon as it appears near them, the whole herd exhibits the most unmistakable signs of terror, rushing about their pasture with their tails in the air, and in case of need taking refuge in the water, where the fly will not follow them. Several other species are known; one of them (*Œ. actæon*) attacks the Red Deer, and another (*Œ. tarandi*) the Reindeer. Those of the allied genus *Cuterebra* deposit their eggs upon the skin of Hares and other rodents.

The *Cephalomyiæ* choose another part of the animal for the reception of their larvæ, which are sometimes produced alive. They introduce their eggs or larvæ into the nostrils of the unfortunate animals on which they are to live, and the larvæ then make their way into the frontal and maxillary

cavities, where they adhere to the mucous membranes by means of the hooks with which their mouths are provided. The larva of the best-known species (*Cephalomyia ovis*) infests the Sheep, and is described as sometimes making its way into the brain, and causing vertigo and finally the death of the animal. The Sheep show their recognition of their enemy very plainly when the fly comes near them, by shaking their heads and stamping on the ground, or, as a last resource, getting into dry, dusty spots, and crowding together with their noses to the ground. The larvæ, when full grown, escape again through the nostrils, and fall to the ground, where they become pupæ. A large species (*C. auribarbis*), which is parasitic on the Red Deer in Germany, is described as shooting its young larvæ into the nostrils of its victim without alighting. The Reindeer has also its peculiar plague of this kind (*C. trompe*).


GASTRUS EQUI.

The larvæ of the species of *Gastrus* or *Gasterophilus* harbour in the stomachs of various herbivorous mammals, but especially of Horses, in which they are well known as "bots." The female of course is unable to introduce her offspring directly into the stomach of the animal on which it is to be parasitic, but she attaches her eggs to the hairs of those parts which are easily reached by the tongue, and indeed are habitually licked. The warmth and moisture of the tongue speedily hatch the eggs, and the parasitic larvæ, by adhering to the organ, are conveyed into the mouth of the victim, whence they easily make their way into the stomach. Here they adhere to the mucous membrane by means of the mouth-hooks, and their presence in any number is by no means advantageous to their host. The best-known species is the *Gastrus equi*. Another (*G. hæmorrhoidalis*) goes directly to the lips of the Horses for the purpose of depositing its eggs. *G. elephantis* inhabits the stomach of the Elephant.

TRIBE V.—PUPIPARA.

This last tribe of the Diptera consists of a comparatively small number of exceedingly curious creatures which are persistently parasitic in their perfect state, which, however, in this case means throughout the whole of their active lives, seeing that the eggs are hatched and the larvæ retained and nourished within the body of the mother until they have arrived at maturity, when they are extruded and immediately pass to the pupa state. Only a single larva is developed at a time. From the structure of the ovaries they cannot be very prolific.


HIPPOBOSCA EQUINA.

FAMILY XXI.—HIPPOBOSCIDÆ.

In this family wings and halteres are generally present, though the insects do not seem to have much occasion for such organs, as they live parasitically upon the bodies of birds and mammals. They have a hard, depressed body; the head is placed horizontally, and bears large eyes; the antennæ are very short; the proboscis consists of the maxillæ and labrum alone, the labium being abbreviated; and the legs are articulated at the sides of a very broad pectoral plate, so that in some cases they seem to spring from the sides of the body. The wings are usually distinctly veined only towards the fore margin; they are sometimes deciduous, and sometimes altogether wanting; the halteres are small, free, and placed low down; and the tarsi have very strong bifid claws.


MELOPHAGUS OVINUS.


LIPOPTENA CERVI.

Hippobosca equina, the type of this family, is parasitic upon Horses; it is well known in the New Forest under the name of the Forest Fly. The Sheep Tick (*Melophagus ovinus*) is another well-known species; it has no wings, and the abdomen is widened posteriorly. The genus *Lipoptena* is peculiar in that the wings are deciduous; and singularly enough, in some cases at any rate, the winged individuals are found on

birds, while those which have lost their wings occur on quadrupeds. Thus *Lipoptena cervi* occurs wingless upon the Stag, and with wings upon Grouse; in the latter condition it has been described as distinct under the name of *Ornithobia pallida.* Many other species live upon birds; sometimes, as in the case of *Ornithomyia avicularia,* infesting many kinds of birds; sometimes confining themselves to particular species or genera, such as *Stenopteryx hirundinis,* which is particularly abundant upon young Swallows.

FAMILY XXII.—NYCTERIBIIDÆ.

The Nycteribiidæ are exclusively parasitic on Bats, and hence are commonly known as "Bat Lice." They are wingless, but have a pair of halteres placed upon the dorsal surface between the articulations of the posterior limbs. The head is very movable, and is usually carried thrown back into a cavity of the upper surface of the thorax; the eyes are small or deficient; the antennæ attached beneath the margin of the head; the proboscis filiform, with very large palpi; the long legs are articulated quite on the sides of the thorax; and the basal joint of the tarsi is very long.

These are curious, ungainly little creatures, more like flattened Spiders than anything; they rarely exceed a sixth of an inch in length, and are parasitic upon various species of Bats, dwelling especially in the cavity of the axilla. They are generally of a pale ochreous or leather colour, with the claws black. The British species live on our common Bats, such as *Vespertilio murinus* and *V. serotinus,* and are sometimes rather abundant. In collections they are rare.

FAMILY XXIII.—BRAULIDÆ.

This third and last family of the pupiparous Diptera includes only a single minute species, which is parasitic upon the Honey Bee, and seems to show a preference for the Drones. It has a large head, with neither eyes nor ocelli; short, two-jointed antennæ, immersed in deep cavities of the forehead; a small, ring-like thorax with a large stigma on each side, and a nearly circular abdomen. The legs are attached to the under surface of the body near the middle line, and the tarsi consist of four short joints and a much longer one at the extremity, the last bearing a pair of singular claws in the form of combs with long teeth. This Bee Louse (*Braula cœca*) is a minute creature about one-eighteenth of an inch long, of a rusty-brown colour. It lives upon the thorax of the Bees, its remarkably pectinated claws being particularly well adapted for clinging to the hairs with which that part is clothed.

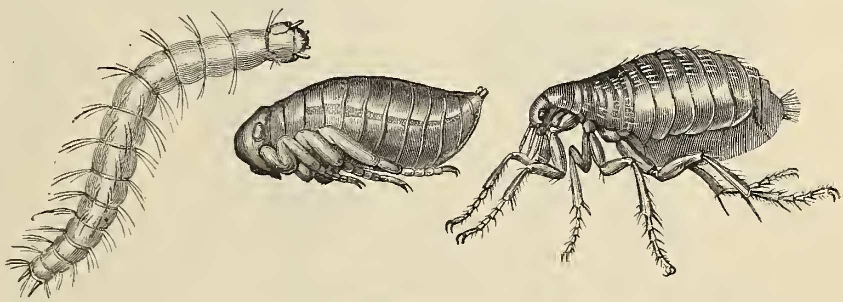
ORDER APHANIPTERA.

This small order includes a few insects which are tolerably familiar to most people, namely, those exceedingly active and very troublesome little creatures, the Fleas. As already stated, they have been of late very commonly classed with the Diptera, but they differ so importantly from all true members of that order that we have thought it better to keep them separate. How far this course is justified will be seen when we have described the general characters of the insects forming the group.

In general form the body, as is probably pretty well known, is considerably compressed, and the insect has no wings. The three segments of the thorax, instead of being soldered together to form a single mass, are separate and similarly constructed, forming three narrow bands behind the head, the only difference between them being that the second and third segments bear on each side a peculiar plate or scale-like piece projecting from their hinder margins. The scales of the mesothorax are small, those of the metathorax much larger, and these parts have generally been regarded as representing the two pairs of wings. Attached to these thoracic segments are three pairs of legs, which are long and powerful. Their coxæ especially are very greatly developed; those of the front pair of legs project forward at the sides of the head, so as to protect the organs of the mouth, and those of the hinder pair are the largest. The trochanters are small; the femora broad and compressed, especially those of the hind legs, which exceed the others in size, and are adapted for leaping; and the tarsi consist of five joints. The eyes are small and round, and the antennæ are minute organs, composed of four joints, and enclosed in little cavities immediately behind the eyes. In the structure of the mouth (see Fig. c., p. 100) the Fleas both resemble and differ from the Diptera. The labrum is rudimentary, but the labium forms a rather delicate membranous organ, which is cleft throughout a good

part of its length, and has the two apical parts more or less distinctly jointed; the maxillæ are short, nearly triangular pieces at the sides of the mouth, but each of them bears a well-developed four-jointed palpus; the mandibles are long and thin, with serrated edges, and slightly hollowed lengthwise, so that when brought together they form a sheath for an unpaired organ (regarded as the same as the epipharynx of the Diptera), which somewhat resembles a three-cornered sword-blade, and is used for the same purpose, namely, that of piercing the flesh and shedding the blood of the bearer's victims. This three-cornered weapon is very deeply channelled below. It is, as already stated, enclosed between the mandibles; the long, cleft, membranous labium embraces these, and the whole constitutes an admirable apparatus for sucking up the blood set free by the puncture of the central piercing organ. The abdomen, which consists of eight segments, is covered, like the rest of the body, with a horny integument, and the hinder edges of all the segments, as also of the scales supposed to represent the wings, are garnished with rows of bristle-like hairs. The legs also are bristly.

It will be seen that in the principle of action of the mouth the Fleas undoubtedly resemble the Diptera, but on the other hand the two divisions of the labium are generally distinctly jointed, and evidently represent labial palpi, and thus, as Dr. Gerstäcker says, these insects form a distinct transition towards the next order (Rhynchota), as also by the segmentation of the body, and especially of the thorax, towards the Orthoptera, "so that they may be characterised as aberrant Diptera, with partial Orthopterous and Hemipterous characters." Insects so characterised are surely best placed in a niche by themselves.



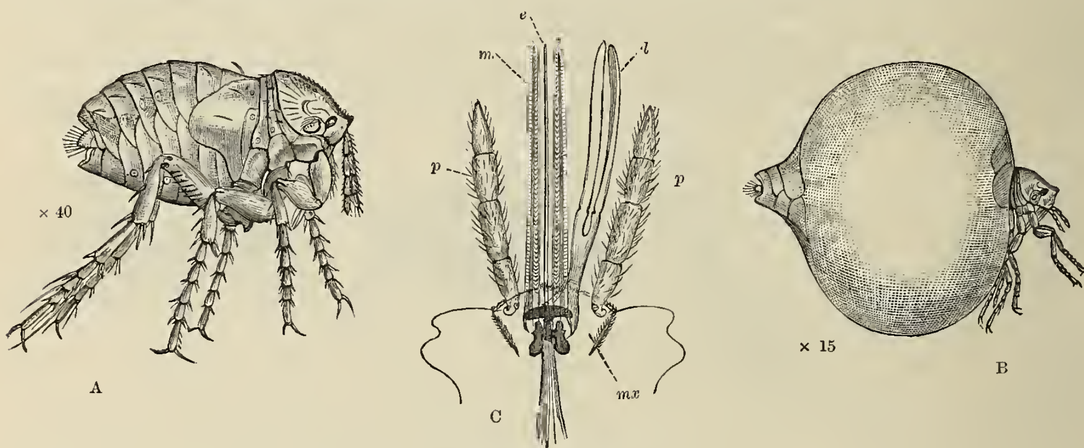
THE METAMORPHOSES OF THE COMMON FLEA.

In their transformations, however, the Fleas present another resemblance to the Diptera, and especially to the earlier families of the order. The eggs, which are usually not numerous, are deposited by the female in suitable places for the development of the larvæ, such as obscure, dusty corners, among the hairs or feathers of the animals infested, or upon the articles on which these animals customarily lie. Thus these "nits" may always be found in the beds of House Dogs and Cats. From the eggs the larvæ are speedily hatched. They are long, worm-like, footless grubs, showing thirteen distinct segments, garnished with fine bristle-like hairs. The head is slightly horny, furnished with a pair of short antennæ and a mouth with biting organs, and the last segment is provided with a pair of horny hooks. These larvæ are active, twisting about in every direction, and feeding upon the nutritious parts of feathers and other refuse animal matter among which they live. In warm weather the larvæ are soon mature (twelve days is the average time in the case of the common Flea), and they then usually enclose themselves in a small silken cocoon, and there undergo the change to the pupa state. The pupa is quiescent, with the different parts enclosed in special cases, and the period during which the insects remain in this condition is usually about equal to that of their larval existence, except in the case of those inhabiting cold and temperate climates, many of which pass the winter in the pupa state.

The perfect insects, as is well known, feed upon the blood of warm-blooded animals, and, as a rule, each species of Flea is allotted to some particular species or group of species of mammals or birds. The insects conceal themselves among the hairs or feathers of the animal on whose blood they are destined to feed, and generally stick to this comfortable and convenient dwelling-place for the remainder of their joint lives, but it is curious to see how soon after the host is killed the parasites escape from its body and show manifest signs of perturbation. The common Flea (*Pulex irritans*) is the best known species, from its habit of drawing its supplies of food from our own persons. The Fleas of the Dog and Cat are distinct (*P. canis* and *P. felis*), and are chiefly confined to those animals, although they do not disdain to vary their diet occasionally with human blood.

Other species are still more particularly limited to certain animals, such as the Squirrel, the Hedgehog, the Mole, Mice and Rats, and Bats. The common Fowl also has its particular Flea (*P. gallinæ*); another infests Pigeons, whilst others are found in the nests of small birds and Swallows. The largest British species lives on the Badger (*P. melis*), and measures an eighth of an inch long; an American species (*P. gigas*) is two lines in length, and a still larger species is described as infesting the Australian Porcupine Ant-eater (*Echidna hystrix*). The common Flea varies a good deal in size in different localities. Very large specimens are said to occur about the bathing accommodations of some watering-places, and the Flea of the old reading-room of the British Museum used to be noted for its magnitude and bloodthirstiness.

The muscular strength of the Fleas is exceedingly great. They perform the most astonishing leaps, covering at a single bound a space many times the length of their own bodies, a faculty which enables them to vanish in the most wonderful manner at the approach of the finger of an intending captor. This extraordinary muscular energy has been taken advantage of in a very curious manner,



SARCOPSYLLA PENETRANS.

A, Free Female; B, Female distended with Eggs; C, Organs of Mouth: *mx*, Maxillæ; *p*, Palpi; *l*, Labium; *m*, Mandibles; *e*, Epipharynx.

Fleas having been trained to drag small coaches and other objects to which they were harnessed, and to perform other tricks, when they were exhibited to an admiring public under the title of "Industrious Fleas."

Besides the ordinary Fleas which occur in all parts of the world upon man and different animals, and which agree closely in their habits and mode of life, we have to notice an American species known as the Nigua, Chigoe, or Jigger (*Sarcopsylla penetrans*), the female of which has certain habits that render her a more unwelcome guest than the fiercest examples of *Pulex irritans*. It is a minute species, less than a twentieth of an inch in length, and lives chiefly in the open country, especially among sand—whence it is sometimes called the "Sand Flea"—but always in or in the vicinity of human habitations, either occupied or deserted. It ranges in America from Paraguay in the South up to Virginia in the North, that is to say, for nearly 30 degrees on each side of the equator, but is particularly abundant in the warmer parts of South America and the West Indies.

In its general habits and transformations, the Chigoe agrees with the rest of the Fleas, and the adult insects feed freely upon the blood of such men and animals as come in their way, until the time comes for the female to produce her eggs, when an entire change takes place in her habits, and she becomes a true parasite. The impregnated female, in fact, makes her way into the skin of the feet of men and animals, generally selecting the toes immediately beneath the nails or claws, but sometimes in the case of small mammals, such as Field Mice, going higher up the limb. In any case, she penetrates the skin until only the extremity of her abdomen is left in contact with the outer air, and it is through very curious stigmata in this part of the body that she now respires. The ovaries produce a great number of eggs, and these gradually swell up the abdomen till it frequently attains the size

of a pea, when nearly all signs of the original segmentation vanish, and the creature appears like a whitish globular bag, with the head and limbs appended to it in front. The skin of the abdomen is thickened, the internal organs become aborted, even the tracheæ disappear, and it would seem that the further development of the ova is effected, after a vegetative fashion, by the mere absorption and assimilation of fluids. When mature, the ova are expelled from the free orifice at the apex of the abdomen.

The older writers gave terrible accounts of the pernicious effects produced by this little insect, but later authorities, and especially Professor Karsten, speaking from observation and personal experience, do not represent it as quite so formidable. It would seem that a slight tickling and itching are the only symptoms produced by the ingress of the parasite, and that if the part in which it resides is not rubbed or irritated, its whole development may take place with no greater inconvenience. Pressure, friction, or irritation of any kind will, however, easily set up an inflammation of the part, and this, if neglected, may assume formidable proportions. Unskilful extraction may also cause disagreeable symptoms, but these are due to mechanical irritation, and not to the deposition of the eggs in the wound produced, as the larvæ are not parasites. The extraction of the insect is generally left until it has attained its full size, when the skin of the toe is carefully pushed aside from the globular abdomen with a knife or needle, and the whole body may then be gently removed. The development of the female usually takes less than a week after penetration into the skin of her victim.

CHAPTER XIII.

THE RHYNCHOTA, OR BEAKED INSECTS.

THE RHYNCHOTA—The Rostrum—General Form—Internal Anatomy—Imperfect Metamorphosis—Distribution—Fossil Species—Classification—HETEROPTERA, OR BUGS—Characters—LAND BUGS—SCUTATA, OR SHIELD BUGS—COREIDÆ—LYGÆIDÆ—PYRRHOCORIDÆ—PHYTOCORIDÆ, OR PLANT BUGS—ANTHOCORIDÆ—MEMBRANACEA—The Bed Bug—REDUVIIDÆ—GERRIDÆ—HYDROCORES, OR WATER BUGS—GALGULIDÆ—NEPIDÆ, OR WATER SCORPIONS—NOTONECTIDÆ—HOMOPTERA—CICADIDÆ—Characters—Distribution—The Organs of Stridulation—FULGORIDÆ—The Great Lantern Fly—MEMBRACIDÆ—CICADELLINA—Cuckoo Spits—Froghoppers—PSYLLIDÆ—APHIDIDÆ—Plant Lice—Hop Fly—Reproduction—COCCIDÆ—Cochineal—PEDICULINA.

ORDER RHYNCHOTA.

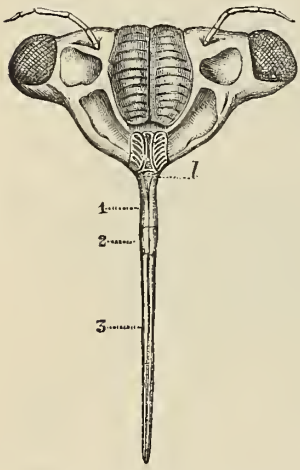
OUR readers will be inclined to think that they are being introduced to very unsatisfactory company. The last chapter treated of Fleas, and in the present one we have to deal with Bugs, and with some other insects, of which we shall at present only say that, according to Sir Hugh Evans, they are familiar beasts to man, and signify love. It is to be observed, however, that these highly objectionable creatures form but a small part of the order Rhynchota; that many of them, though often unsavoury, are of great beauty; and that the natural history of others is exceedingly interesting.

The Rhynchota constitute the first order of insects with an imperfect metamorphosis, and they have the mouth converted into a suctorial apparatus. They were placed by Linnæus in the same order as the Grasshoppers, Cockroaches, and allied forms which compose the typical section of the next order (Orthoptera), and the name of Hemiptera, which he gave to this composite group, bears reference to the peculiar construction of the fore wings in the Bugs. This name is still often applied by entomologists to the present order, but as it applies only to one division of the order, and its original use was very much wider, we have preferred following the example of the majority of continental writers and adopting the name Rhynchota ("beaked insects"), which expresses the leading character by which the order is distinguished.

As in the case of the Diptera, the suctorial organ in the typical Rhynchota, which is commonly denominated the *rostrum*, includes in its composition all the principal parts of the mouth. The actual rostrum is a horny jointed organ, forming a longer or shorter tube, cleft above towards the base, and formed by the labium and its palpi, the latter making two half tubes, united in the middle line both above and below, and showing along one surface a suture of junction in continuation of

the basal cleft already mentioned. This cleft is closed by the more or less elongated labrum, which fits into it, and thus completes the tube. Within this tube we find four bristles representing the mandibles and maxillæ, which can be pushed forward and retracted by the action of muscles attached to their slightly enlarged bases, and thus serve, like the similar organs of the Diptera, to pierce the tissues of animals and plants, and enable the insects to suck up their juices. There are no maxillary palpi.

The general form of the body varies exceedingly, and so does the relation of the head to the thorax, but, as a rule, the three segments of the thorax are distinct and separate, and bear two pairs of wings, the texture of which differs much in the different subordinate groups. Usually the prothorax is greatly developed on the upper surface, and behind it we find a regular scutellum. In both these respects, as also in the frequent conversion of the fore wings into horny wing-cases, the Rhynchota resemble the Beetles. The tarsi never consist of more than three joints. The abdomen is formed of from six to nine segments, which, in those species which have horny fore wings, are horny only on the lower surface, and on this the stigmata are situated.



HEAD OF CICADA PLEBEJA.
l, Labrum; 1, 2, 3, Joints of Rostrum.

Unlike the Diptera and Lepidoptera, the Rhynchota have no crop or sucking stomach appended to the œsophagus, which leads directly into a glandular stomach, followed by a long, convoluted intestine, often dilated in its course into a stomach-like sac. The last portion of the intestine is also frequently glandular, and receives the Malpighian vessels, of which four are generally present. The salivary glands are usually much developed and often of complicated structure, or furnished with complex salivary receptacles. Besides these glands, we find in the Bugs a glandular organ situated in the metathorax, which secretes a strongly and generally disagreeably scented fluid, discharged through a pair of special orifices close to the origin of the posterior pair of legs. The nervous system is very much condensed. Behind the head-ganglia the ventral chain generally shows only two thoracic ganglia, of which the second is larger than its fellow, and evidently composed of two ganglia united into a single mass. The abdominal part of the chain is represented only by a pair of nerve-cords, from which nerves are given off to the various organs. In nearly all the Rhynchota we find a pair of compound eyes, generally of small or moderate size, and either two or three ocelli. The other sense-organs, the antennæ, vary greatly in structure, being sometimes quite short, composed of two or three joints and terminated by a bristle, sometimes long, and then consisting either of four or five joints of considerable length, or of a greater number up to about twenty.

The metamorphosis throughout the order is imperfect; indeed, in the PEDICULINA, there is no metamorphosis at all. The larvæ present a greater or less resemblance in general form to the perfect insect, and as they grow and change their skin the rudiments of the wings make their appearance and gradually increase in size, lying in cases placed on each side behind the prothorax. There is consequently no true pupa stage, the imago being gradually produced under the successive larva skins until the final moult; but the last stage before this takes place is usually denominated the pupa. The insect is active and has similar habits throughout its life, the only exception to this rule being presented by the males of the Cochineal insects, which become resting pupæ underneath the last larva skin, and are sometimes enclosed in a small cocoon.

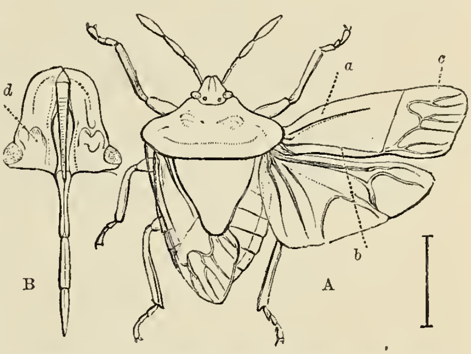
The food of most of the insects of this order consists of the juices of plants, which they suck up after piercing the tissues, as above mentioned, with the bristles which represent the mandibles and maxillæ. Some of these vegetable feeders have been observed occasionally to attack other insects and feed upon their juices, and the species of certain families are predaceous in their habits, and live entirely upon animal food. The *Pediculi* are parasitic upon Mammalia, whose blood they suck.

The species are found in all parts of the world, but the tropical regions are most favourable to their development, and it is here that we meet with the greatest number of species, and that they attain the largest size, the most curious forms, and the finest colours. Some of them are among the

most brilliant of insects. The number of known species is hard to estimate, but it is probably not less than 18,000.

From the descriptions of palæontologists it would appear that the Rhynchota are of great antiquity in the history of the world. Three species have been recorded from the Carboniferous formation, two of them being regarded as most nearly resembling the existing Fulgoridæ, or Lantern Flies. The Lias of Schambelen has furnished Prof. Heer with several fossil species belonging to this order, and representing both the principal groups into which the typical forms are divided; while the rich deposits of Solenhofen (Upper Oolite) contain a still larger number of species, some of them of considerable size. In England also the Lower Lias has furnished remains of Rhynchota, but none seem to have occurred in the Stonesfield Slate, or elsewhere in the English Oolites, until we come to the uppermost or Purbeck beds, in which such insects are tolerably numerous, and represent several existing families. It is as usual in the Tertiary beds that the traces of this order become most numerous, and in the deposits of Œningen and Radoboj, so admirably worked out by Prof. Heer, the majority of the existing families are represented by more or less well-preserved examples.

The parasitic Pediculidæ (the Sucking Lice), which we place as degraded forms of this order, differ from the rest in so many important characters, but especially in the soft, fleshy, and retractile nature of their rostrum and the complete absence of wings, that we may fairly regard them as constituting a distinct sub-order, for which the name of PEDICULINA can be adopted. The remainder, or the typical Rhynchota, with very few exceptions, all possess the jointed rostrum above described as generally characteristic of the order, and in the exceptional cases this organ is altogether suppressed and not transformed into a fleshy sucker. These insects, however, may be divided into two groups, which are generally distinguished with facility by the structure of the fore wings. In one of them, including the numerous species of Bugs, the anterior wings almost invariably consist of two distinct parts, namely, a basal division, which is usually horny or leathery, and an apical part, which is more or less membranous. Hence the organs are commonly known as *Hemelytra*, and the sub-order is called HETEROPTERA. The membranous parts of the two wings, which are only occasionally absent, cross over one another at the apex of the body. The true wings are folded up beneath these hemelytra when closed. In the great majority of the species the rostrum originates at or towards the front of the head, and this character will serve to show the affinities of those species in which the wings are rudimentary or imperfectly developed. In the second sub-order the fore wings are of the same consistence throughout, or at any rate do not show that distinct division into two parts which is characteristic of the Heteroptera generally; hence they are called HOMOPTERA. The fore wings may be horny or leathery; the hind wings are membranous, and generally smaller than the anterior pair. The latter generally do not cross each other at the apex when closed, but they are almost always placed upon the sides of the body in a sloping direction, meeting along the middle line in the form of a roof, whereas in the Heteroptera the closed wings generally lie flat upon the upper surface of the body. The two sub-orders further differ in the position of the rostrum, the face in the Homoptera being turned downwards, so that its true apex is brought into close contact with the sternum, and it is from this point that the jointed rostrum springs. Among the Heteroptera a somewhat similar arrangement occurs only in one family (Notonectidæ). The Heteroptera are regarded as the highest of the three groups, followed by the Homoptera, while the Pediculina constitute a somewhat aberrant series, although included by some entomologists under the Homoptera.



A, PENTATOMA DISSIMILE; B, UNDER SIDE OF HEAD AND ROSTRUM.
a, Corium; *b*, Clavus; *c*, Membrane; *d*, Tubercles for the Antennæ.

SUB-ORDER I.—HETEROPTERA, OR BUGS.

The characters distinguishing this group have already been sufficiently indicated for general purposes, but a few further details are necessary. The fore wings generally form protective coverings

for the more delicate hinder pair, and lie horizontally upon the upper surface of the body. From their function, and their being composed of two parts, they are, as has been said, generally denominated *hemelytra*; the horny basal part is called the *corium*, and the inner portion of this, bordering the scutellum, and marked off by a more or less distinct suture, is distinguished as the *clavus*. The thin apical part is the *membrane*, and generally shows some veins, the number and distribution of which are of importance in the discrimination of groups and species. The ocelli are generally present, and two in number. The antennæ, except in the aquatic families, are more or less elongated, and composed of four or five joints. They may be of about equal thickness throughout, or clubbed or reduced to a hair-like fineness at the extremity; in some instances some of the joints show signs of division, and the antennæ then look as if composed of more than five joints. These insects form two tribes, the members of which are respectively terrestrial and aquatic in their mode of life.

TRIBE GEOCORES, OR LAND BUGS.

The term "Running Bugs" would, perhaps, better express the habits of the insects of this tribe, as some of them frequent the water and even run briskly over its surface, while the members of the second tribe are essentially swimmers. The distinction of the two groups is, however, exceedingly easy, the Land Bugs having the antennæ freely exposed, and generally of moderate length, while in the Water Bugs those organs are of small size and concealed in cavities beneath the eyes.

FAMILY I.—SCUTATA, OR SHIELD BUGS.

The distinctive character referred to in the name of this family is the large size of the scutellum, the apex of which always reaches the base of the membrane (see Fig. A, p. 103), while in many cases the scutellum is so large as to cover nearly the whole upper surface, concealing the greater part of the hemelytra. The rostrum consists of four joints, and the labrum is long, reaching beyond the first joint of the rostrum, and transversely striated. The antennæ are usually of five joints, but sometimes only of three or four, attached to tubercles which are almost always concealed beneath the margins of the head (see Fig. B, p. 103), and there are two ocelli. The basal joint of the rostrum lies in a channel of the under side of the head.

These insects live upon plants, trees, and shrubs, and feed upon the juices which they suck out of the soft tissues, many of them especially attacking juicy fruits. Some species, however, have been detected in the act of varying this diet by imbibing the fluids of caterpillars. The family includes some of the largest of the Bugs, and is particularly well represented in the warmer parts of the globe, where also the most beautifully coloured species are met with. The *Callideæ*, for example, and the members of several genera nearly allied to them, inhabiting the tropical parts of the eastern hemisphere, are perfect gems when alive, showing the most splendid metallic tints, diversified with black spots. These belong to the section of the family in which the scutellum covers the whole back of the abdomen; one species (*Callidea Stollii*) appearing dark blue with black spots, is very common in boxes of Chinese insects. But many other forms have during life a very fine metallic colouring which disappears after death. Traces of this may occasionally be seen in a very large species which is also a common inmate of the Chinese boxes (*Tesseratoma chinensis*), the specimens of which are usually over an inch long, and of a rather light brown colour with darker legs. The scutellum in this insect is triangular in form, as in the majority of the British and European species, which are not very numerous. One of the best known is the Red-legged Bug (*Tropicoris rufipes*), which measures about two-thirds of an inch in length, and has the sides of the prothorax produced into broad, pointed processes, and the tip of the scutellum occupied by a reddish spot, the rest of the surface being of a bronze-brown colour, with numerous large black punctures. A very pretty little native species, which lives on cruciferous plants, and is said sometimes to injure the cultivated varieties, may be called the Colewort Bug (*Strachia oleracea*). It is of a blue or greenish colour, variegated in the female with red and in the male with white markings. A nearly allied species (*S. ornata*), bright red with black markings, frequents the flowers of umbelliferous plants. Many exotic species of the same form show similar bright colours. The largest species belong to a special group, of which the Chinese *Tesseratoma* already referred to is an example. They have the rostrum much shorter than in the rest of the family, and the lateral angles of the prothorax

often produced into spines or horns. These are found in the warmer parts of both hemispheres, especially in South America and the East Indies. Those from the former belong chiefly to the great genus *Edessa,* and to some allied genera with five-jointed antennæ, while the majority of the Oriental species have those organs of four joints.

In temperate climates these insects generally keep themselves in concealment among herbage or the foliage of trees and bushes, but occasionally they fly freely in the sunshine. They winter in the winged state under the shelter of dried leaves or in moss, &c. The eggs are laid in the spring, and are of an oval or rounded form, furnished with a little lid which the larva pushes off in emerging.

FAMILY II.—COREIDÆ.

In this second family of the Geocores the scutellum is triangular, but does not reach the base of the membrane, the inner portions of the hemelytra (*clavus*) meeting beyond its apex in a straight suture. This character is common to most of the species of all the succeeding families. The antennæ are of four joints, and spring from tubercles placed on the sides of the head above an imaginary line drawn from the eyes to the base of the rostrum. The rostrum is four-jointed, with the basal joint usually the longest; the head bears two ocelli; and the hemelytral membrane has longitudinal veins, which are generally, as in the Scutata, rather numerous.

The number of European species is but small, and their size is generally insignificant, but in the tropics the species are very numerous, and generally of considerable size, some of them being the giants of the terrestrial Bugs. Many attain a length of an inch, while a few are an inch and a half or two inches long. Some of these large species, and a great many of the smaller ones, have the hinder thighs much thickened, especially in the males, while in some of these, and in others with slender thighs, the posterior tibiæ are toothed, or dilated in a remarkable manner. This is particularly conspicuous in the South American genus *Anisoscelis,* and the allied genus *Diactor.* A species of the latter is figured of the natural size in Plate 63, J. In a good many species the third joint of the antennæ is compressed or even more or less dilated, and in a few the second joint partakes of the same character. Some have the lateral angles of the prothorax produced into spines, or even into broad processes, which in a few are curved forward so as to give the prothorax a very marked crescent-like form. In a considerable number of species the body is comparatively narrow, the abdomen being scarcely wider than the closed hemelytra; in others the margins of the abdomen are wide, and project far beyond the sides of the hemelytra. This is the case in the most characteristic British species, *Syromastes marginatus* and *Verlusia rhombea,* the specific names of which relate to the prominence of the margins of the abdomen. Others, such as the species of *Berytus* and *Neides,* are exceedingly narrow and linear in their general form.

The insects of this family are rarely adorned with bright colours, different shades of brown being the prevailing tints, although some are more gaily adorned. In their general habits they much resemble the Shield Bugs, being found upon plants and trees, and flying readily during the heat of the day. The larger species produce a loud humming noise when on the wing. Their food appears to consist for the most part of vegetable juices, but some entomologists believe that they are more predaceous in their habits than the Shield Bugs.

FAMILY III.—LYGÆIDÆ.

The members of this family are, on the whole, much smaller than the Coreidæ, some of the smallest forms of which many of them much resemble. They also have a short, triangular scutellum, two ocelli, and four-jointed antennæ, but the latter organs spring from below a straight line drawn from the eyes to the base of the rostrum. The rostrum is of four nearly equal joints. The membrane of the hemelytra has usually four or five longitudinal veins.

The nearest approach to the preceding family is made by the typical genus *Lygæus,* which also includes the largest species. These insects are generally of a red colour with black bands and spots. None of these occur in Britain, but several species are found on the continent of Europe (*Lygæus equestris, L. saxatilis, L. familiaris,* &c.), all of which seem to have a wide distribution. The family is chiefly composed of a multitude of small species forming the genus *Rhyparochromus* and its allies, in which the body is usually black, and the corium of the hemelytra of some light brownish

or yellowish tint. The insects are found chiefly upon plants during the summer and autumn, and in moss or under dead leaves in winter. A few, such as *Platygaster ferrugineus*, which is very flat, winter under the bark of coniferous trees.

FAMILY IV.—PYRRHOCORIDÆ.

These insects, which may be denominated "Red Bugs," approach the typical Lygæidæ in some respects, especially in their being generally of a bright red colour with black spots and other markings, but they may be at once distinguished by the absence of ocelli, and the presence of numerous longitudinal veins in the membrane. They are found in most parts of the world, but, like the other families, are more abundant and much larger in warm than in temperate climates. They are much more predaceous in their habits than any of the preceding.

PYRRHOCORIS APTERUS.

One species of this especially tropical family occurs in the south of England, and is exceedingly abundant on the continent of Europe. It is known as *Pyrrhocoris apterus*, the specific name having reference to the absence of the wings and of the membrane of the hemelytra in most specimens found in cold or temperate regions. It is about a third of an inch long, and of a scarlet colour, with the head, the disc of the prothorax, the scutellum, the clavus, a spot upon each hemelytron, and the abdomen and limbs black. These insects usually occur in great numbers together, so as to produce the appearance of bright red patches about the foot of the trees, especially lime trees, which they frequent. They feed upon the juices of plants and fruits, but also to a great extent upon fluid sucked from the bodies of other insects, not even sparing young individuals of their own kind.

FAMILY V.—PHYTOCORIDÆ, OR PLANT BUGS.

These insects agree with those of the last family in wanting the ocelli; they also have a rostrum and antennæ composed of four joints; but they differ from all the preceding Bugs in the structure of the hemelytra. In these organs the outer apical angle of the corium is cut off from the rest by a transverse suture, so that it forms a separate triangular piece (*appendix*); and the only veins in the membrane itself form one or two cells at its base. The integuments of the body are rather soft, and the antennæ have the second joint long and the third and fourth usually very slender.

The Phytocoridæ abound in most parts of the world, and in Europe and Britain are undoubtedly the most numerously represented of all the families of Bugs. They may be found in the greatest abundance during the summer upon plants, bushes, and trees, and especially upon the low herbage of hedge bottoms. Several species may always be obtained during the summer from the nettles which usually

grow in the last-mentioned situation. They feed chiefly upon the juices of the plants on which they live, and on which they run with great rapidity when disturbed; they also fly freely in bright weather. A very common species on nettles is the *Phytocoris tripustulatus*, which is about a sixth of an inch in length and of an oval form. Its general colour is yellowish, with black markings on the hinder margin of the prothorax, the scutellum bright orange, and the hemelytra nearly black, with three orange yellow spots on the outer margin, the hindmost of which occupies the appendix. In the genus *Capsus* and its allies, the second joint of the antennæ is thickened, especially towards its apex. *Capsus capillaris*, which is also abundant upon nettles, varies in colour from red to black, but has always a red spot in the appendix. This species is rather more than a quarter of an inch long. A rather smaller species (*Capsus ater*) is common upon herbage; the male is entirely black, in the female the head and thorax are reddish. The genus *Miris* and its allies include elongated species, which are found chiefly in grassy places.

FAMILY VI.—ANTHOCORIDÆ.

Under this title we include a number of generally minute Bugs, which show curious affinities to the Lygæidæ, to the Phytocoridæ, and to certain species of the next family, especially the Bed Bug, which, indeed, has been included in the present group by some entomologists. They are small flat-bodied insects, having antennæ of four joints, with the last two generally more slender than the preceding ones, two ocelli, a rostrum apparently or really of three joints, and not enclosed in a furrow, and elytra, when fully developed, possessing an appendix like that of the Phytocoridæ. The membrane has a basal cell, from which three or four short veins usually proceed. Few of the species exceed an eighth of an inch in length; the largest of our native forms (*Anthocoris nemorum* and *A. nemoralis*) do not attain more than the sixth of an inch. They are elliptical, black, with the hemelytra paler, but with dark or black markings; the front of the head, in most species of the group, is produced between the bases of the antennæ as a sort of snout. They are common on different kinds of trees and bushes during the summer months, and often frequent dead branches. Other species are found either all the year round or during the winter in the dead branches or under the bark of trees, whilst others are to be met with among vegetable rubbish of various kinds. Although so small and delicate in their structure, they appear to be predaceous in their habits, sucking out the juices of other insects and their larvæ.

FAMILY VII.—MEMBRANACEA.

In this family we have a slightly heterogeneous assemblage of forms, which, however, are certainly nearly allied to each other, and have generally been placed together by entomologists. They agree in the possession of four-jointed antennæ and of a three-jointed rostrum, which is enclosed in a sort of channel formed by a pair of keels running down the lower surface of the head and the sternum as far as the rostrum extends, in the flattened form of the body, and in having tarsi with only two joints. The ocelli are generally absent. In the majority the antennæ are thickened or clavate at the extremity, but in the Bed Bug and some allied species the third and fourth joints are more slender than the first and second.

The Bed Bug (*Acanthia lectularia*), which is only too well known to most people, besides the character of the antennæ just mentioned, is further distinguished by the rudimentary condition of the wings, the hind wings being altogether absent, and the hemelytra represented only by a pair of little convex organs, like small shells, situated just behind the prothorax. Although treated as a British insect, it does not appear to have been always an inhabitant of these islands, but to have made its way here about the beginning of the sixteenth century. Even now there are many out-of-the-way places even in England where the insect is still unknown. The notion that it was introduced and spread by the importation of timber from America seems to be quite unfounded, as the Bed Bug was certainly known to the ancients, and is mentioned by both Greek and Roman authors.

THE BED BUG.

Three other British species have been described as inhabiting the dwelling-places of certain animals and feeding on their blood; *A. columbaria* attacking pigeons, *A. hirundinis* found in martin's nests, and *A. pipistrelli* feeding on Bats. The first of these is very near *A. lectularia* and may not be distinct. A few more species are known from different parts of the world.

In the remainder of the family the hemelytra and wings are generally well developed, but the insects exhibit the same flattened form as the unwelcome inhabitant of our sleeping rooms, and like it are able to make their way into very confined spaces. Many of them reside habitually under the loose bark of dead trees, where they are generally found associated in some numbers. *Aradus depressus*, the most abundant native species of these Bark Bugs, is less than a quarter of an inch long, blackish-brown with lighter granules, with the greater part of the lateral margins of the prothorax yellowish-white, and the hemelytra of the same colour, but mottled and variegated with brown. It is found under loose bark and in moss. These insects are probably predaceous, but according to some writers they feed on fungi.

The species of the genus *Tingis* and its allies are minute and exceedingly delicate creatures, having the margins of the thorax and the whole of the hemelytra quite membranaceous and generally reticulated with numerous veins. One of the best known species (*Monanthia cardui*) is found abundantly upon thistles. It is about an eighth of an inch long, of a greyish colour, variegated with small black spots. Other species are still more elegant, having the membranous parts quite transparent, with black veins. They are found upon various trees and plants, chiefly herbaceous, upon the juices of which they appear to feed.

In the insects just mentioned the scutellum is usually concealed by a projection of the hinder margin of the thorax; in another group of the family it is exposed, and sometimes even attains a large size. These insects, which are generally inhabitants of warm countries, have the fore legs converted into raptorial organs, and possess two ocelli. Two species (*Syrtis crassipes* and *S. monstrosa*) are found in Central and Southern Europe.

FAMILY VIII.—REDUVIIDÆ.

This is a great group of insects presenting much analogy with that which we have included under the family Coreidæ, both in general form and in the modifications which that form undergoes in the various members, but differing from them nevertheless in several important characters. They have the head of various forms, but always constricted behind so as to form a regular neck, and in front of this there are two distinct ocelli. The antennæ are four-jointed, with the last two joints generally thinner than the first and second; the rostrum, which is not enclosed in a furrow, is composed of three joints, and is generally a short, stout, and powerful organ; the legs are generally long, with short, three-jointed tarsi, and the anterior pair are sometimes converted into raptorial limbs. All these insects, the species of which are exceedingly numerous in tropical regions, are predaceous in their habits, attacking and sucking out the juices

REDUVIUS PERSONATUS.

of other insects, a predatory course of life for which the powerful typical species are particularly well fitted. Many of them, when seized, will inflict a severe wound upon their captor.

The largest British species is *Reduvius personatus*, an insect about three-quarters of an inch long, of a blackish-brown colour, with reddish legs. It is well furnished with wings, and flies especially in warm summer evenings, when it frequently enters houses, being attracted by the lights. Its larva, which haunts concealed corners, disguises itself by means of a covering formed of its own excrements mixed with extraneous particles, and both larva and perfect insect, when in houses, are said to display a special enmity to the Bed Bug. Three or four species of the genus *Nabis* occur in Britain on herbage, generally under the shelter of bushes. They are nearly elliptical, but more narrowed in front, and generally of a brownish tint on the upper surface. The hemelytra and wings are often imperfectly developed in these insects. A near ally of theirs, a very scarce British species, is of a beautiful blue-black, with the hemelytra and legs bright scarlet, but the former are never fully developed in northern examples. Its name is *Metastemma gattula*, and it represents a group of Bugs, of which the typical genus is appropriately named *Pirates*, including some of the largest and most powerful insects of this family.

The very opposite peculiarities are presented by the *Hydrometra stagnorum*, which in many respects leads us towards the next family. It is a slender, elongated creature, about half an inch long, with the antennæ and legs also exceedingly long and thin, which is found on the margins of pieces of water crawling slowly about upon aquatic plants and the vegetable *débris* which generally occur in such situations. The articulations of the legs are situated at the sides of the thoracic segments, as in the Bugs of the following family, and the insect occasionally walks upon the surface of the water just as they do.

FAMILY IX.—GERRIDÆ.

This last family of the Geocores includes some exceedingly well-known insects, which may be seen running actively over the surface of every piece of water. They have a broad head, which is not contracted behind into a neck, four-jointed antennæ and a three-jointed rostrum, of which the second joint is the longest. The legs are inserted quite at the sides of the thorax, and the tarsi are of two joints, with the claws inserted, not at the apex of the last joint, but in a notch of its under side. These insects, of which several species are abundant in Britain, have boat-shaped bodies, and the typical forms, such as *Gerris lacustris*, which may be met with anywhere, literally row themselves along the surface of the water by means of their long legs, their power of floating being aided by the coating of silvery hair which covers their lower surface and carries with it a portion of air. They are predaceous in their habits, feeding upon other insects. Some nearly allied, but mostly very small species, with legs even longer in proportion than those of our common forms, are met with at sea within the tropics, and often at a great distance from land. They form two or three genera, of which the best known is *Halobates*.

TRIBE II.—HYDROCORES, OR WATER BUGS.

As already stated, these insects are distinguished by the possession of very short antennæ concealed in pits near the eyes. The tribe includes three families, two of which are well represented in Europe and Britain, while the third is exclusively American. The last-mentioned family is the most nearly related to the preceding forms.

FAMILY X.—GALGULIDÆ.

This family is at once distinguished from the rest of the tribe by the presence of a pair of ocelli on the crown of the head. The body is flat, and the head broad and immersed up to the eyes in the thorax; the eyes are prominent; the antennæ composed of four joints; the rostrum three-jointed, and the membrane of the hemelytra small. The legs are formed for running, and the species live on the banks of rivers and lakes, where they prey upon other insects. The best-known species (*Galgulus oculatus*), an insect about two-fifths of an inch long, of a blackish-brown colour, inhabits the southern parts of the United States. The fore legs have the femora thickened, and are somewhat raptorial in character, and this peculiarity is much more strongly marked in the species of *Mononyx*, which are found in South America, and in which the fore tarsi are represented only by a sort of claw.

FAMILY XI.—NEPIDÆ, OR WATER SCORPIONS.

In this family the ocelli are wanting, the antennæ are either three or four-jointed, the body is flat above, elliptical or much elongated, and the hemelytra are furnished with a distinct membrane. The rostrum is of three joints. The fore legs in all are raptorial; the remainder are either simple, fringed, or flattened, but in all cases are used as swimming organs. All the species live in the water and prey upon their weaker fellows. They are, however, well furnished with wings, and can fly readily, a provision which is useful in case of any need arising for seeking a new abode.

The common Water Scorpion (*Nepa cinerea*) is a very well-known aquatic insect, and is abundant in the fresh waters of all parts of Europe. It is about an inch long, elliptical, yellowish-grey, with the back of the abdomen red; the antennæ have three joints; the hinder legs are scarcely fringed, and have tarsi of a single joint; and the body is terminated by a pair of tail-like organs, which, when put together, form a breathing tube. The insect is sluggish in its movements. The female attaches her eggs to water plants. They have at the upper end seven radiating processes. The *Ranatræ*, which resemble the preceding in the characters of the antennæ, tarsi, and air-tube, have a very elongated body, whence the British species is called *Ranatra linearis*. They have the fore legs much lengthened, and the four hinder tibiæ rather more fringed than in *Nepa*.

RANATRA LINEARIS AND NEPA CINEREA.

Another division of the family having four-jointed antennæ, two-jointed hinder tarsi, and no breathing tube, is represented in Britain by a small oval species, about half an inch long, of an olive brown tint, known as *Naucoris cimicoides*. It has a broad, deeply-immersed head; the anterior tarsi consist of a single joint; and the hinder tibiæ and tarsi are fringed, so that the insect is a more activ swimmer than the Water Scorpion. When handled it is able to inflict a painful wound. Some of the exotic allies of this species are among the giants of the order, or indeed of the insect world. Thus the *Belostoma grande*, a native of South America, measures over four inches in length. This must be a most formidable enemy to the weaker inhabitants of the fresh waters of Brazil and Guiana, as besides its large size, it is favoured by having the hinder legs widened into regular paddles, which must enable it to swim with great rapidity. Other allied species of nearly equal size occur in the tropical parts of both hemispheres. The females of some of the smaller tropical forms (*Diplonychus*, &c.) deposit their eggs close together upon their backs, and thus carry them about.

FAMILY XII.—NOTONECTIDÆ.

The Notonectidæ have a broad head with the forehead rounded and turned down, so that the insertion of the rostrum is brought close to the anterior margin of the sternum. The body is convex

above and flat below; the antennæ are four-jointed; the ocelli are wanting; and the hinder tibia and tarsi are much compressed and strongly fringed on both sides, rendering the insects very active swimmers. The familiar name of "Water Boatmen" is often applied to the typical forms of this family, in allusion to the appearance they present when resting and taking in air at the surface of the water; the long hinder legs are then thrown out nearly at right angles to the body after the fashion of a waterman resting on his sculls (see centre figure on p. 110).


NOTONECTA GLAUCA.

The British *Notonecta glauca* is an insect rather more than half an inch long, of a yellowish colour above, with the scutellum black. As implied in its name, it swims with its lower surface upwards, and is exceedingly expert in that exercise, while it also flies very well by means of a pair of most beautiful filmy wings which are folded up beneath the roof-like hemelytra. It is a most predaceous insect, and can bite severely.

Still commoner than the above are the species of the genus *Corixa*, the largest British representative of which (*Corixa Geoffroyi*) is nearly half an inch long. These insects, which are flatter on the upper surface than the true *Notonectæ*, are to be met with in nearly every piece of stagnant water. They swim with their backs upwards, and are not so powerful and active as *N. glauca.*

SUB-ORDER II.—HOMOPTERA.

As already pointed out, the most striking general character of this group consists in the uniform texture of the fore wings, which never show the clear division into corium and membrane exhibited by the great majority of the Bugs. The wings also do not, except in a few instances, cross each other at the tip, and in by far the greater number they are placed slantingly on the sides of the body, so as to make a roof-like covering. Where the wing characters are obscure the position of the origin of the rostrum will at once determine to which division an insect belongs. In all the Homoptera this organ springs from the hinder part of the lower surface of the head close to the sternum (see figure on p. 102), or even in some cases apparently from the sternum itself. These insects all feed upon vegetable juices.

FAMILY XIII.—CICADIDÆ.

The insects forming this family, which have always been placed at the head of the Homoptera, are of moderate or large size and robust conformation, and may be at once distinguished from all the rest by the possession of three very distinct ocelli upon the crown of the head. The head itself is generally broad, short, and vertical, and terminated below by a rather long rostrum composed of three joints. The forehead is considerably inflated, and marked with fine transverse furrows; the eyes are prominent; the short antennæ originate close to the eyes, and are of seven joints, which gradually diminish in thickness so that the organ is like a bristle; the scutellum is large, inflated, and notched behind; and the fore wings are much larger than the posterior pair, and generally show only a moderate number of very definitely arranged veins.

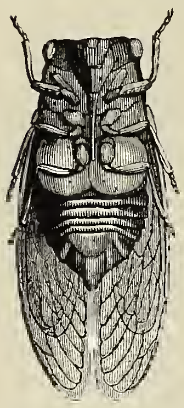
Of the four or five hundred known species of this family, by far the greater number inhabit tropical countries, and it is in such regions that the species attain the greatest size. Thus, *Tacua speciosa* (Plate 63, A.), a magnificent black species, with a broad yellow band across the hinder margin, and part of the anterior margin of the same colour, is a native of Java and the neighbouring islands. The females often measure over three inches in length when the wings are closed, and species of equal, or nearly equal, dimensions are met with throughout the tropical parts of the world. A large black species with transparent wings (*Fidicina atrata*) is common in Chinese boxes, which also contain a rather smaller form, black with yellow spots (*Gæana maculata*), and a still smaller black species with the forehead, two large spots on the mesothorax, and the abdomen blood red (*Huechys sanguinea*). On the continent of Europe about eighteen species are recognised, and one of the smallest of these (*Cicada hæmatodes*) occurs in the south of England, in the New Forest, where, however, it seems to be rare.


LARVA AND PUPA OF CICADA.

These insects live upon trees and shrubs, and obtain their nourishment by piercing the tissues and sucking out the juices of their young tender shoots. In some cases the flow of juice continues after the withdrawal of the pumping apparatus of the Cicada, and the fluid hardening on the surface of the twigs becomes the substance known as *Manna.** This applies especially to a species that infests ash-trees in most parts of Europe and over a considerable portion of Asia (*Cicada orni*), which is, in fact, the common Cicada of Southern Europe.

The female Cicada is furnished with a powerful serrated ovipositor, by means of which she cuts deeply into the dead branches of the trees on which she lives, and deposits her eggs in the grooves thus formed. The larvæ, when hatched, are little, plump, stout-limbed insects, and they speedily make their way beneath the surface of the ground, where they live by sucking the juices from the roots of trees and plants. They appear generally to pass at least two years in their preparatory states, and some are said to be much longer in arriving at maturity. One North American species is called the *Seventeen-years' Locust* (*Cicada septendecim*), because it is said to appear only at intervals of seventeen years in any given locality.

The male Cicadæ are endowed with a noise-producing power which renders them most troublesome in places where they abound. During the heat of the day they sit concealed among the foliage of the trees and shrubs, and sing incessantly. This habit has been referred to by the classic poets in many passages, which indicate that for some reasons the song of the Cicada was regarded by them as by no means unpleasant, and, in fact, even at the present day, in countries where the insects abound, it is a common practice to keep them in cages, probably for the purpose of reminding town-dwellers of the delights of the country. The organs by which this often violent stridulation is produced are situated at the base of the abdomen, in two cavities enclosed by large horny plates, which are represented upon a smaller scale in the females also. The special organs enclosed in these cavities consist of elastic folded membranes attached to a horny ring, and the noise has generally been described as produced by vibrations of these membranes, caused by the action of muscles originating from the median partition of the second abdominal segment. According to Dr. Landois, however, the "drum," as the above-mentioned special membrane has been called, cannot act in the manner described, but is firmly attached to the wall of the metathorax. He considers the true organs of sound to be the stigmata of the metathorax, which are very large and elongated, and furnished throughout their length with a pair of thin sound-bands, leaving a very narrow slit between them. The vibration of these bands during the expulsion of air from the tracheæ produces the sound, which the external organs only increase in power. The females have no voice, as was well known to the ancients—in fact, one Greek poet most ungallantly congratulates the male Cicadæ on the silence of their partners.



UNDER SURFACE OF MALE CICADA.

FAMILY XIV.—FULGORIDÆ.

In these insects, as in the two succeeding families, there are never more than two ocelli, but these are rarely wanting, and are placed near the compound eyes. The head is exceedingly variable in its form, but the forehead is always separated both from the crown of the head and from the cheeks by well-marked ridges or keels. The antennæ, which consist of three joints, and are usually short and terminated by a bristle, spring from the cheeks beneath the eyes; the prothorax is a simple ordinary segment; the middle coxæ are elongated and widely spread, and the tibiæ are generally three-cornered and often spinous. The hind limbs are usually leaping organs, and their tibiæ have a circlet of spines at the apex, often accompanied by one or two of larger size. There is no trace of singing organs such as are possessed by the Cicadæ. In many of the Fulgoridæ the front of the head is produced into processes, sometimes of the most fantastic form; and most of them produce from the skin a sort of waxy secretion, which usually forms white powdery-looking patches on the abdomen, but is frequently much more abundant, and constitutes stout white threads, which may entirely cover and conceal the abdomen, and extend for some distance beyond its apex. This

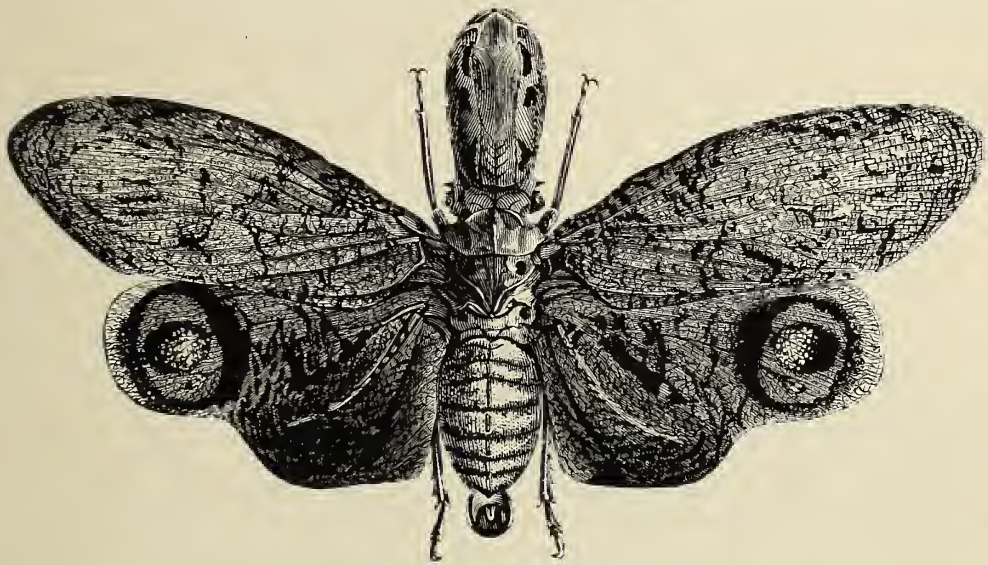
* Most of the manna of commerce, however, is obtained artificially by incisions made in the bark of the ash-trees.

EXOTIC RHYNCHOTA.

A, Tacua speciosa; B, Fulgora candelaria; C, Cercopis bivittata; D, Tettigonia quadripunctata; F, Heteronotus reticulatus; F, Membracis elevata; G, Membracis cruenta; H, Hypsauchenia balista; I Hemiptycha punctata; J, Diactor bilineatus.

secretion is produced by the larvæ as well as the perfect insects. That of a Chinese species (*Flata limbata*) is collected for sale, and known in commerce as "Chinese white wax."

The processes of the head in the typical Fulgoridæ are often of considerable size, and, according to the older writers, had the power of diffusing a considerable amount of light from their extremity, whence the insects are commonly known as "Lantern Flies." The Great Lantern Fly (*Fulgora laternaria*), a native of Surinam, Brazil, and other parts of the South American Continent, attains a length of nearly three inches, and its wings spread nearly twice that distance. Its head-process, or lantern, is about an inch long, stout, and much inflated, with two large humps on the upper surface. The general colour is yellowish-brown, but each hind wing has a large, orange-yellow, ocellated spot, bordered with dark brown, and enclosing two bluish pupils. It is this insect, especially, that has been described as luminous; but the researches of modern travellers, if they



THE GREAT LANTERN FLY.

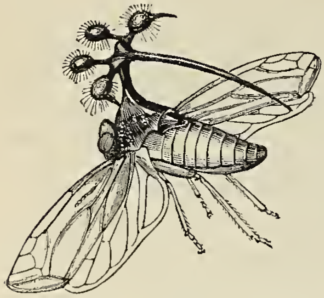
have not altogether disproved its possession of this property, have, at least, rendered it exceedingly doubtful. The Chinese Lantern Fly (*Fulgora candelaria*), a very common insect in all Chinese boxes, is shown in our Plate 63, B. It has a red body, greenish fore wings with yellow spots, and orange hind wings with black tips. Many other forms of these flies, with or without head-processes, are found throughout the tropics.

The European and British species are all of small size, and generally of dull colours. They are found upon trees, shrubs, and herbage. *Cixius nervosus*, an insect rather more than a quarter of an inch long, is black, with yellow legs, and transparent fore wings, in which the veins are dotted with brown, and there are two transverse brown bands. It is found chiefly on alders. The species of the allied genus *Delphax* occur principally on herbage; in *Asiraca* (*A. clavicornis*) the antennæ are elongated, nearly half as long as the body; and in *Issus* (*I. coleoptratus*), the ocelli are indistinct, and the fore wings are leathery and humped, like a pair of convex elytra.

FAMILY XV.—MEMBRACIDÆ.

If in the Fulgoridæ the head occasionally, as we have seen, takes on a fantastic shape, in the Membracidæ the prothorax fairly astonishes us by the extraordinary forms which it assumes. It is enlarged and produced into processes of the most varied kinds, and very frequently has a posterior part which wholly or partially covers the abdomen and wings. The head is bent down, furnished with two ocelli, and with a pair of very short antennæ, but the crown of the head is not separated in any way from the forehead. The wings are generally membranous. The species of this very remarkable family, which includes some of the most *bizarre* of insects, are chiefly inhabitants of

America, where they occur in wonderful abundance and variety. Our figures (E, F, G, H, I, in Plate 63) will show some of the curious forms that they assume. Some of the most remarkable are the species of *Bocydium*—black insects, with transparent wings, the prothorax of which bears a perpendicular process, terminating in a knob, from the sides of which issue two branches, also branched and knobbed, whilst from behind is given off a long slender process, extending about as far as the extremity of the closed wings. Several species occur in South America, and from the slenderness of these singular thoracic processes, some of them are very elegant little creatures.



BOCYDIUM TINTINNABULIFERUM.

The extra-American species of this group belong chiefly to the genus *Centrotus*, one species of which (*C. cornutus*) is common in Britain and Europe. It is rather over a quarter of an inch long, black, with a pair of upright horns on the prothorax, which is also produced behind into a long, pointed, keeled spine. Another common European and British species (*Gargara genistæ*) is smaller than the preceding, and has no horns on the prothorax.

FAMILY XVI.—CICADELLINA.

We apply this term to a very extensive group of Homoptera, of small or moderate size, which in many respects may be regarded as the analogues of the Phytocoridæ among the Bugs. In these insects we find the prothorax of ordinary form and proportions, without any of those enlargements or processes which characterise the preceding family, and the head, instead of being pressed downwards, projects freely in front of the thorax, with the crown directed upwards and the forehead forwards, the two surfaces usually meeting under a distinct angle. There are usually two ocelli; the antennæ are short, and composed of two joints with a terminal bristle; the upper wings are leathery; and the hind legs elongated and converted into leaping organs. These insects are distributed over all parts of the world, and, with the exception of the Aphides, they constitute the most numerously represented group of Homoptera in Europe and Britain. They live in all stages upon trees, shrubs, and plants, on the juices of which they feed, and the larvæ and pupæ very commonly surround themselves with a dense frothy secretion, whence the common name of "Cuckoo-spits" has been applied to them.

Two groups of these insects may be distinguished, and these are usually easily recognised by the form of the hinder limbs. In the CERCOPIDÆ these organs are smooth, or furnished only with two or three spines arranged one behind the other on their hinder surface, and the posterior coxæ are short. This group includes the largest species, some of the exotic species attaining a length of about an inch. A Javanese species approaching this length (*Cercopis bivittata*) is shown on our Plate 63, C. It is shining black, with two white bands across the fore wings. Black and red are more common colours in the genus *Cercopis*, one species of which, so adorned (*C. sanguinolenta*), is common on the continent, and occurs in Britain. The most abundant European species of this group, however, are the *Aphrophoræ*, which are the best known of the Cuckoo-spits, or Froghoppers. *Aphrophora spumaria*, an insect nearly half an inch long, is common in Britain on trees and bushes, especially willows; a smaller species (*A. bifasciata*) is found abundantly upon rose-bushes and other plants in every garden.

The JASSIDÆ have the hinder coxæ transverse, and the hind tibiæ furnished with two rows of more or less distinct spines along their posterior surface. They are exceedingly numerous, and often remarkably elegant in form. The species of *Tettigoniæ* (*T. quadripunctata*, Plate 63, D) especially are frequently of great beauty. They are mostly inhabitants of America, whence some three or four hundred species have been described, but we have in England an exceedingly pretty green species (*T. viridis*), which is common in damp meadows. The species of *Typhlocyba*, which are exceedingly abundant on plants everywhere, resemble the *Tettigoniæ* in general form, but are more slender, and generally very small and delicate creatures. They have no ocelli.

FAMILY XVII.—PSYLLIDÆ.

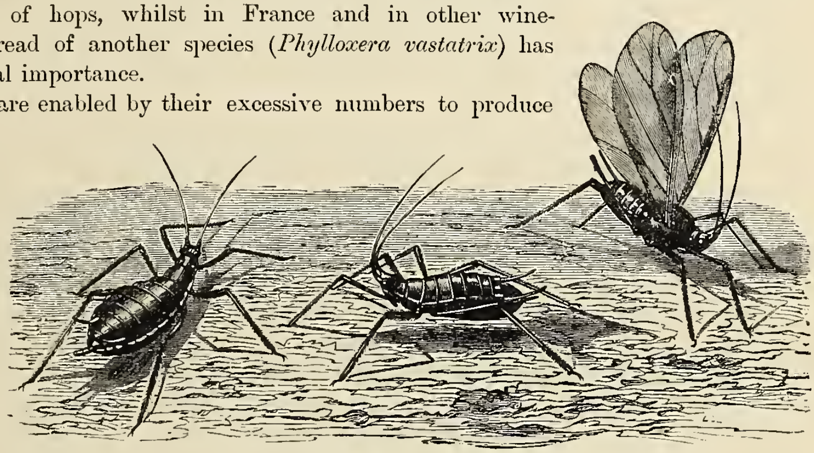
This is the first family of the so-called Plant Lice, and is distinguished by having long, freely-projecting antennæ of eight or ten joints, with a pair of fine bristles at the extremity of the last joint,

three ocelli, and short legs with the femora thickened, adapting the insects for springing, which they do with as much activity as the Froghoppers. The tarsi are of two joints, and the fore wings are generally somewhat leathery. These are minute insects which live upon various plants and trees, each species, however, usually being restricted to some particular kind of plant. Their bodies, especially those of the larvæ, generally show a powdery white coating, analogous to that noticed as occurring in the Fulgoridæ. The species rarely exceed an eighth of an inch in length. By attacking the young shoots, and especially the inflorescence of trees, the larvæ often give rise to considerable deformation of the parts. Common species occur upon the alder, the ash, the pear-tree, the oak, and the nettle.

FAMILY XVIII.—APHIDIDÆ.

This exceedingly interesting family, which includes the insects commonly known as "Plant Lice," is so abundantly represented everywhere, that some of its forms must be familiar to all our readers. Every one must have noticed the green Aphides which swarm upon roses, and the black ones of the bean, whilst a host of other species, more or less resembling these, are to be found upon almost every plant in the garden or the field. Small and feeble as they are, they often force themselves upon the attention of the farmer and the gardener by the injury they do to cultivated plants. In this country the abundance or scarcity of the Hop Fly (*Aphis*, or *Phorodon humuli*) is a most important matter to the cultivator of hops, whilst in France and in other wine-growing countries the spread of another species (*Phylloxera vastatrix*) has become a matter of national importance.

The creatures, which are enabled by their excessive numbers to produce such serious results, are individually of the very feeblest. They have a soft, tender body, generally of an ovate shape, and usually long, thin, and feeble legs; their tarsi are of two joints; their antennæ are more or less elongated, composed of from five to seven joints; the crown of the head has no ocelli; and the rostrum is three-jointed, sometimes very long, but sometimes altogether wanting in certain developmental forms. The wings also are frequently deficient, sometimes in all the individuals of a species, sometimes again in particular developmental forms. When present they are membranous, with few veins, generally resting in a roof-like form over the abdomen, and the hind wings are much smaller than the anterior pair. In most of the species the abdomen bears a pair of tubes or perforated tubercles upon the last segment but two. From these, which are known as honey-tubes or *corniculi*, a sweet fluid is poured forth in small drops, and is a great attraction to Ants and many other Hymenopterous and Dipterous insects. When secreted in great abundance this fluid often drops from the branches of the trees infested by Aphides, and is then commonly known as "honey-dew."



THE ROSE APHIS.

These insects generally live on the leaves and tender shoots of trees, shrubs, and herbaceous plants, the tissues of which they pierce in order to suck out the juices. They are sluggish creatures, generally remaining fixed in the same spot, with the rostrum deeply inserted; but they can shift their position to short distances by slow and feeble walking, and make wider excursions by the aid of the wings with which some forms of each species are generally provided. In many cases the attacks of the Aphides are directed to the roots of plants, and some of these are taken possession of by Ants, who treat them as herds of miniature milch-cows (see Vol. V., p. 381), but it seems doubtful whether these forms, which are always apterous, are more than stages of the development of species, other forms of which live above ground. A few species belonging to the genus *Lachnus* and its allies, which have the rostrum very long, live in the fissures of the bark of trees. One example,

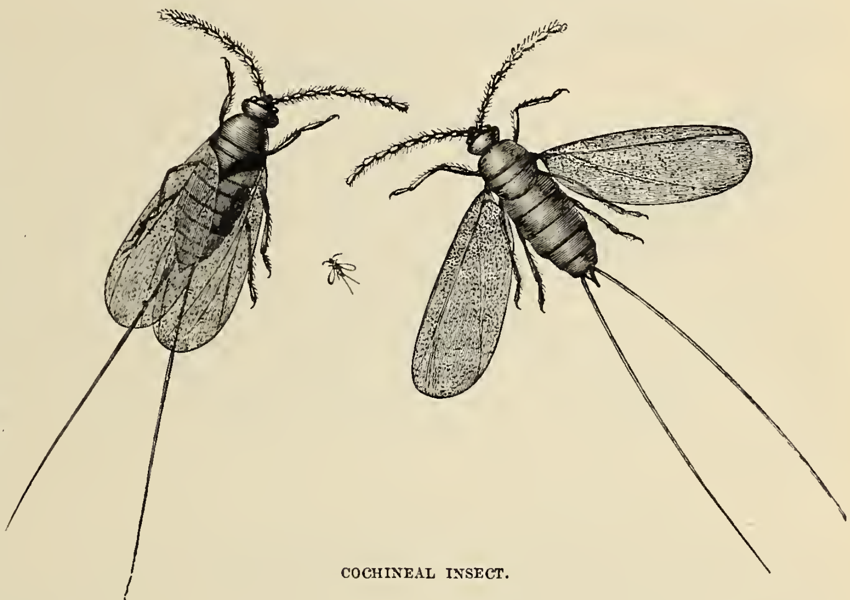
known commonly as the "American blight" (*Schizoneura lanigera*), a small insect covered with a white cotton-like secretion, often does much injury to apple-trees. Three species of *Lachnus* are found upon the oak. Of the species haunting the leafy parts of trees, a considerable number produce great deformations of the parts they attack, which grow out into gall-like or bladder-like structures, within which the Aphides reside. The leaves and leaf-stalks are the parts chiefly affected in this way, and the effect produced varies from a mere crinkling of the leaf to the formation of a regular sac having only a narrow slit of communication with the outer world. Such structures may be constantly found upon poplars and the various kinds of willows and sallows.

The reproduction of the Aphides constitutes one of the most interesting chapters in the history of the Animal Kingdom. In the late autumn, males and true oviparous females make their appearance, and the latter, after fertilisation, deposit their eggs in sheltered situations, where they remain until the spring. Among the progeny of these eggs there are no males, and after changing their skins three or four times the insects arrive at their mature form, when they give origin, asexually, to another generation also of asexual forms, and this process goes on throughout the summer. These asexual forms are generally viviparous, the young being produced by a process of internal budding from organs representing the ovaries of the perfect females, and they usually show, at the time of their birth, the rudiments of the next generation. These asexual forms may be either winged or wingless, and their production under favourable conditions may go on for a long time. Thus Bonnet observed the production of nine, and Duvau of eleven generations, whilst Kyber, by keeping a colony of Aphides in a warm room, was enabled to continue their asexual reproduction for four years. This, therefore, is a very complex case of "alternation of generations," the whole of the individuals produced between one asexual generation and the next having to be regarded as larval forms, whether winged or apterous. It would appear, however, from recent investigations, and especially from those of M. Jules Lichtenstein, that matters are not quite so simple as above stated, at all events, in the case of some species observed by him, though how far his results will apply to the whole family is at present a matter for further investigation. In the case of the Phylloxera of the oak (*Phylloxera quercus*), M. Lichtenstein states that the egg, which is attached to the bark of *Quercus coccifera*, produces at the end of April an apterous form which he terms the *foundress.* This changes its skin four times, and then produces asexually egg-like bodies (*pseudova*), which it attaches to the petiole and lower surface of the leaves. These pseudova produce the first larval form, which is apterous and larger than any of the succeeding forms. It gives origin to the second larval form, which acquires wings and migrates in May to another species of oak (*Quercus pubescens*), under the leaves of which it settles, then produces egg-like bodies, from which the third larval form originates. This is apterous and viviparous, producing its like by internal gemmation, and this process may be continued several times. It is this third larval form the reproduction of which was observed by the writers above cited. Towards the autumn a fourth larval form appears, which acquires wings and returns to the *Quercus coccifera*, where its progeny consists of larvæ which develop into sexually perfect male and female insects, which are apterous and destitute of a rostrum. The females produce a single large egg. M. Lichtenstein's observations upon other species seem to show that analogous processes of reproduction prevail widely among the Aphides, but how far this may be the case is at present doubtful. The whole question is one of great interest, and one to the solution of which any person possessing leisure and patience might easily contribute. The history of the Aphides also presents many other points of interest, and the beautiful monograph of the British species by Mr. Buckton published by the Ray Society will greatly facilitate its study.

FAMILY XIX.—COCCIDÆ.

This family, chiefly formed by the Cochineal insects and their allies, is a curious one, and in some respects differs greatly from all the other Rhynchota. The Coccidæ usually have beaded antennæ, composed of six or more joints; they have two-jointed tarsi; the wings are generally wanting in the females, and the hind wings in the males, which also have the rostrum suppressed. The metamorphosis is peculiar. The larvæ are small, tortoise-like creatures, which run about freely upon the plants which they frequent. When full grown, the females without any particular change of

form attach themselves by the rostrum to some juicy part of the plant; while the male larvæ, which frequently betake themselves to the more solid portions, undergo a process of change which is peculiar to them among the Rhynchota. Beneath the scale-like skin of the larva the male insect becomes converted into a resting pupa, and the first indication of his being ready to emerge is the protrusion, from the hinder part of the protecting scale, of a pair of fine white caudal bristles. The male then soon makes his escape, coming out of his case backwards, so that the two delicate wings with which he is provided are pulled up completely over his head. He is a rather elegant creature, with a pair of perfect wings, the hind wings being represented by a sort of halteres; but his partner, making good use of the ample supply of nourishment at her command, has in the meantime become rather obese, and may be found adhering to the shoots of the plant, with scarcely any recognisable trace even of the original segmentation of her body. In most cases, in fact, the females might be taken for excrescences of the plant rather than insects. When numerous, the females often do much injury to cultivated plants and trees. Thus *Lecanium hesperidum* attacks the orange, and another species (*Coccus adonidum*) is often mischievous in hot-houses. They are known to gardeners as Scale-insects, or, shortly, as "the Scale." The female, after fertilisation, deposits her eggs between the lower surface of her body and the surface on which she rests. As the eggs are extruded the body of the mother shrinks, until her dried integuments serve as a protective covering to the mass of eggs.



COCHINEAL INSECT.

If some of the species are injurious, others have proved of much value to mankind, such as the true Cochineal insect (*Coccus cacti*), a native of Mexico, which furnishes the most valuable and durable red dye that we possess, and the Lac insect (*Coccus lacca*), an East Indian insect, which produces the well-known lac-dye, and also by its punctures causes the exudation from the trees of the resinous substance shellac. The former feeds on a cactus, the latter on the Indian fig and some other trees. *Porphyrophora polonica* lives on the roots of a *Scleranthus* in Germany and Poland, and was much esteemed as a red dye before cochineal was generally known in Europe. Many of these insects show a white coating on their surface, and this attains a remarkable development in a peculiar species which is common on nettles, and called *Dorthesia urticæ.* The female is so covered with the white secretion that it looks like a little piece of chalk. The female of this insect is active throughout its life. In *Aleurodes chelidonii* both sexes possess four wings, and this insect forms a very clear transition towards the Aphides. It is common on the greater celandine (*Chelidonium majus*).

SUB-ORDER III.—PEDICULINA.

The Pediculina, or true Lice, form the last and lowest group of the Rhynchota, of which they must be regarded as very degenerate forms. They have no wings; the thorax is small, and its segments are not very distinct; the abdomen is oval, and composed of nine segments; the antennæ consist of five joints; the eyes are small and simple; and the six legs are well developed, with two-jointed tarsi, the first joint being small, and the second larger and claw-like, and folded back upon the first like the blade of a knife upon its haft. The mouth consists of a fleshy sheath (the labium),

furnished at the end with two rows of minute horny hooklets, and enclosing a much finer protrusible tube, probably representing the other parts of the mouth, and the whole is so completely retractile that when not in use nothing can be seen of any part.

These insects constitute a single family (Pediculidæ), and are all parasitic upon various Mammalia, each species being usually confined to some particular animal. They crawl about among the hairs of their host, to which they readily cling by means of the clasping tarsi. They live upon the blood which they suck from its tissues. The females attach their eggs to the hairs near their insertion into the skin. In the case of the common Louse of the human head, the young are hatched in about nine days, and take about eighteen days to attain their full growth. The known species are not very numerous, probably in part owing to the disagreeable associations attaching to the very name of these insects. Man is subject to the attacks of three, if not four species, namely, *Pediculus capitis*, inhabiting the head; *P. vestimenti*, infesting the clothed surface of the body, and *Phthirius pubis*, which is also a body Louse, but is confined to particular regions. The fourth species is the *Pediculus tabescentium*, which has been described as occasionally appearing upon a patient in immense numbers, and producing a disease known to the ancients as phthiriasis, and said to have been sometimes fatal. In all cases the best mode of getting rid of such unwelcome guests is a thorough application of oil of turpentine or some other essential oil.


PEDICULUS CAPITIS.

CHAPTER XIV.

ORDER ORTHOPTERA.

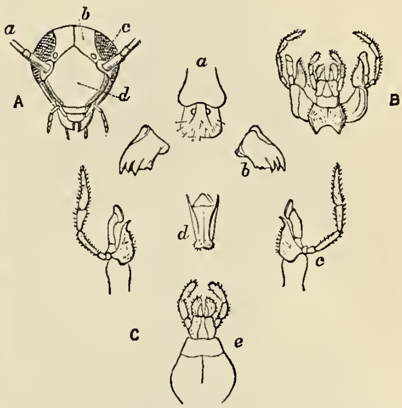
ORTHOPTERA—Characters—Structure — Internal Structure—Metamorphoses — Distribution — Classification—THE ORTHOPTERA GENUINA—TRIBE SALTATORIA—THE GRYLLIDÆ, OR CRICKETS—The House Cricket—The Field Cricket—The Mole Cricket—THE LOCUSTIDÆ—The Great Green Grasshopper—THE ACRIDIIDÆ, OR GRASSHOPPERS—Locusts—TRIBE CURSORIA—THE MANTIDÆ—Praying Insects—Soothsayers—THE PHASMIDÆ, OR WALKING STICKS—Walking Leaves—THE BLATTIDÆ, OR COCKROACHES—The Common Cockroach—The Gigantic Cockroach, or "Drummer" —TRIBE EUPLEXOPTERA—THE FORFICULIDÆ, OR EARWIGS—THE PSEUDONEUROPTERA—TRIBE SOCIALIA—THE TERMITIDÆ, OR WHITE ANTS—TRIBE CORRODENTIA—THE EMBIIDÆ—THE PSOCIDÆ—TRIBE PLECOPTERA—THE PERLIDÆ—The Stone Fly—Pteronareys—TRIBE SUBULICORNIA—THE EPHEMERIDÆ, OR DAY FLIES—May Fly—THE LIBELLULIDÆ, OR DRAGON FLIES—THE PHYSOPODA—Thrips—THE MALLOPHAGA—*THE THYSANURA*—Lepisma—THE COLLEMBOLA—Spring-tails—Podura.

THE Orthoptera, as already stated, include all the forms of insects with an imperfect metamorphosis and a biting mouth, of which the parts are exposed so as to be more or less recognisable externally; they have frequently appendages at the extremity of the abdomen, but these never serve as locomotive organs, as is usually the case in the following order. The members of the order, however, present so much diversity of character that there is but little to be said about the group in general: in fact, it may be a question whether the differences presented by the various subordinate types are not really in part of ordinal value; indeed, some of them have actually been formed into distinct orders by different entomologists.

There is, however, one peculiarity characteristic of all but certain low and aberrant forms of the order, namely, the division of the lower lip (*labium*). This organ in the most typical forms shows four, or in other cases two, distinct lobes in front, and the ligular part behind these is cleft in the middle, so that the precise equivalence of the labium to a second pair of maxillæ is at once apparent (see figure on p. 119); even when the parts are not so distinct as is here shown, there is always an indication of the median cleft, showing that the labium is composed of a pair of maxilliform organs. In the Dragon Flies we find this structure somewhat masked, but it is still recognisable by careful study; and various modifications of the organ occur in other groups. The maxillæ generally have a distinct outer lobe, known as the *galea* (or helmet), from the mode in which it overtops the inner biting lobe; the maxillary palpi are usually well developed, and composed of five, or even seven, joints. The eyes are usually of moderate or large size, but sometimes represented by an aggregation of simple eyes on the sides of the head; the ocelli are seldom wanting

and when present they are more frequently three than two in number. In the antennæ we find the same difference as in the Rhynchota, these organs being either long and thin, generally thread-like or bristle-shaped, and composed of numerous joints, or small organs, consisting of two or three basal joints and a bristle, which, however, may be jointed.

In the structure of the thorax there is considerable difference, although the three segments are generally separate. The prothorax is frequently of large size, forming the principal part of the thorax as seen from above, but sometimes it is much reduced, representing a sort of ring-like neck; the meso- and metathorax are well developed, and in the great majority of the species are furnished with wings. These latter organs are entirely wanting in the parasitic forms that we refer to the order, and in a few members of other groups; but in general we find four wings, which, however, differ greatly in texture. Thus in one great section of the order the fore wings are of a leathery or horny consistence, generally forming protective coverings (*tegmina*) for the hind wings, which are more membranous, and in which the veins radiate from a central point to the margin, so that in repose the wings fold together after the manner of a fan; whilst in another great division both pairs of wings are membranous, and serve as organs of flight, and the veining of both pairs is more or less alike. The legs are very various in their character.



HEAD AND MOUTH ORGANS OF COCKROACH.
(*After Griffith and Henfrey.*)

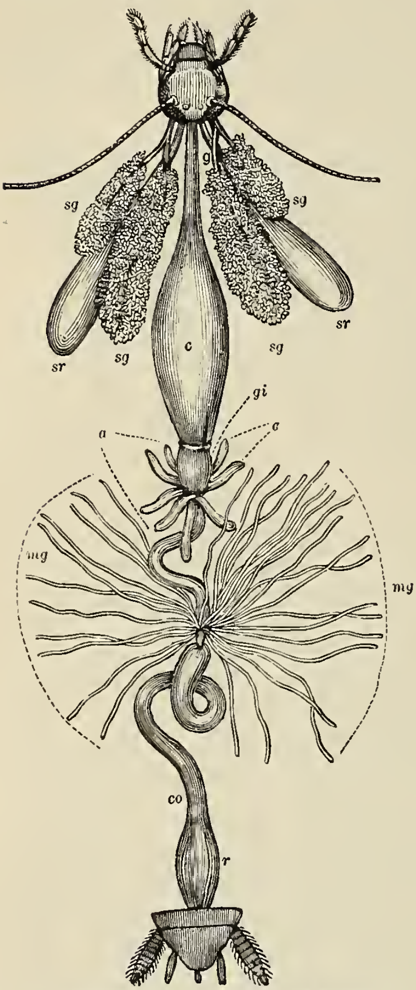
A, head (*from before*); *a*, antennæ cut off; *b*, epicranium; *c*, eyes; *d*, clypeus. B, under portions. C, mouth organs; *a*, labrum; *b*, mandibles; *c*, maxillæ; *d*, internal tongue; *e*, labium.

Like the labium, the abdomen shows in its structure traces of approximation to the ideal type of insects, inasmuch as in many cases this part of the body shows the whole number of eleven segments (see Fig. 2, p. 282, Vol. V.). The extremity of the abdomen is often furnished with appendages of various kinds, sometimes with long and slender bristles, sometimes with stouter jointed tails (*cerci*), and occasionally with horny processes, which may take on the form of forceps. In some forms the abdomen of the female is furnished with an ovipositor, which represents the ventral plate of the ninth abdominal segment, the genital and anal orifices being here separated, and placed, the former in the ninth, the latter in the eleventh segment.

Of the internal structure of the Orthoptera in general we can say but little. The intestinal canal (see figure on p. 120) is rarely much longer than the body. The œsophagus is followed by a gizzard, or proventriculus, chiefly in those forms which live upon an animal or mixed diet, and the salivary glands are more highly developed in the same species. In most Orthoptera the Malpighian vessels are short and numerous. The ventral nervous chain follows the generalised type of the segmentation of the abdomen, the abdominal ganglia, as well as the thoracic, being distinct, and united only by commissures, except at the extremity of the chain, where two or more of the abdominal ganglia are united into a mass. A remarkable character of this ventral chain is that it is so long that if stretched out it would extend beyond the abdomen, and it consequently forms one or more curves in its course through the body. The tracheæ are frequently dilated into air-vesicles in those forms which possess much power of flight.

Of the preparatory stages of these insects little need be said. The parasitic and apterous forms appear to undergo no changes of consequence, and the larvæ of a great number of the higher types are almost exactly like their parents, except for their smaller size and the absence of wings. In some cases, however, including nearly all the forms which pass their preparatory stages in the water, there is rather more difference between the larva and the perfect insect, although the former is still active in all its stages. In all the development is quite gradual; the young larvæ are destitute of any traces of wings, which, however, soon make their appearance beneath the skin behind the prothorax, and go on increasing in size with each moult, until the final change takes place. During this process the number of joints in the antennæ, and the number of facets in the compound eyes, usually increase with each change of skin. The larvæ seek the same diet as the perfect insects, and are generally exceedingly voracious.

The geographical distribution of the Orthoptera is very wide, no family being strictly confined to the warmer regions of the earth, but all extending their range at least as far as the south of Europe, and most of them having representatives in much higher latitudes. Nevertheless, even of those groups which are best represented in cold and temperate climates, the species are usually far larger and more numerous in warm and tropical countries, to which, indeed, some of the families are chiefly confined. The total number of known species may be estimated at about 6,000.



ALIMENTARY CANAL OF COCKROACH.
g, œsophagus; *c*, crop; *gi*, gizzard; *mg*, malpighian glands; *sg*, salivary glands; *sr*, salivary receptacles.

We have already seen that in certain structural characters the Orthoptera remarkably approach what may be imagined to be the original type of "the Insect," and it is therefore not surprising to find that Orthoptera are the very earliest types of insects that have been discovered in the fossil state. In Devonian rocks in America remains of various forms belonging to this order, and especially to its most generalised and central type—that of the Cockroaches—have been met with, together with others which certainly seem most nearly related to the forms with veined membranous wings, constituting our second subordinate group; similar types occur in the Carboniferous and Permian formations on both sides of the Atlantic; and others gradually make their appearance, showing characters which enable them to be referred to existing families, such as the beautifully preserved Dragon Flies of Solenhofen, and numerous other forms which are met with in a more or less imperfect state in Secondary rocks. In the Tertiaries they become still more numerous, and still more closely allied to the living forms.

It is somewhat difficult to hit upon a satisfactory classification of these insects, but the following will serve our purpose of indicating the alliances of the different types. We divide the Orthoptera as here understood into four sub-orders, of which the first (ORTHOPTERA GENUINA) includes the forms upon which the order Orthoptera was originally founded by Latreille. A second group, PSEUDO-NEUROPTERA, is formed by the membranous-winged types formerly referred to the order Neuroptera. The order is completed by two groups of small insects, namely, the PHYSOPODA, including the various species of Thrips, the true position of which is somewhat doubtful; and the MALLOPHAGA, which may be described as mandibulate lice. The comprehension of the sub-orders and tribes into which we propose to divide the Orthoptera will be facilitated by the following tabular arrangement:—

I.—With Wings (except in a few forms).

A. Mouth of ordinary construction:—

1. Fore wings horny or leathery (*tegmina*) . . . Sub-order 1.—ORTHOPTERA GENUINA.

a. Hind wings with veins radiating from the base, fan-like:—

* Hind legs formed for leaping . . . Tribe 1.—SALTATORIA.

† Hind legs formed for walking . . . „ 2.—CURSORIA.

b. Hind wings with veins radiating from the apex of a horny piece occupying the base of the anterior margin . . . . . . „ 3.—EUPLEXOPTERA.

2. Wings all membranous	Sub-order 2.—PSEUDONEUROPTERA.
a. Wings, with few and simple veins, and those of the disc obsolete; tarsi 4-jointed; living in societies.	Tribe 1.—SOCIALIA.
b. Wings with few and simple veins, all horny; tarsi 2—3-jointed	„ 2.—CORRODENTIA.
c. Wings reticulated:—	
* Antennæ long; hind wings folded in repose .	„ 3.—PLECOPTERA.
† Antennæ short; hind wings not folded in repose	„ 4.—SUBULICORNIA.
B. Mouth resembling a rostrum; mandibles bristle-like; wings narrow and fringed	Sub-order 3.—PHYSOPODA.
II.—No wings or metamorphoses; Parasites	„ 4.—MALLOPHAGA.

SUB-ORDER I.—ORTHOPTERA GENUINA.

This sub-order, as already stated, represents the order Orthoptera of the older entomologists. The group is characterised by the texture of the wings, which are rarely wanting in the perfect insects; the fore wings being of a leathery consistence, and serving as a protective covering for the hind wings when folded up, after the fashion of the elytra of Beetles; and the hind wings, the sole or principal organs of flight, showing a number of strong primary veins, which radiate from a central point like the sticks of a fan, and between these generally a reticulation of finer veinlets. The head is always of considerable size, and the parts of the mouth powerfully developed, the mandibles being strong, and having their inner margins strongly toothed, and the maxillæ large, and terminating in two principal lobes, of which the outer one (*galea*) usually overtops the inner one. The maxillary palpi consist of five, and the labial palpi of three joints. The eyes are usually large, and often prominent; the ocelli are frequently altogether wanting, but when present they are generally three in number. In the development of the legs there is considerable diversity, these organs being sometimes long and slender, sometimes of moderate length and stouter; the fore legs are sometimes converted into raptorial or fossorial organs, and the hindmost pair often form powerful leaping limbs. At the end of the abdomen, in the females of many species, we find an ovipositor, and this part is also most commonly furnished, in one or both sexes, with peculiar styles, or with longer, jointed, tail-like organs, which are called *cerci*.

These true Orthoptera may be readily divided into three tribes (see Table, p. 120), namely, the Leapers, or SALTATORIA; the Runners, or CURSORIA; and the Earwigs, or EUPLEXOPTERA.

TRIBE SALTATORIA.

Contrary to the usual practice of entomologists, we have commenced with the Saltatorial Orthoptera, our object in so doing being to bring as near together as possible in the middle of the order the Cockroaches and White Ants, which are not only nearly related, and thus form the link between the two sub-orders Orthoptera and Pseudoneuroptera, but are also the most generalised types round which the others group themselves.

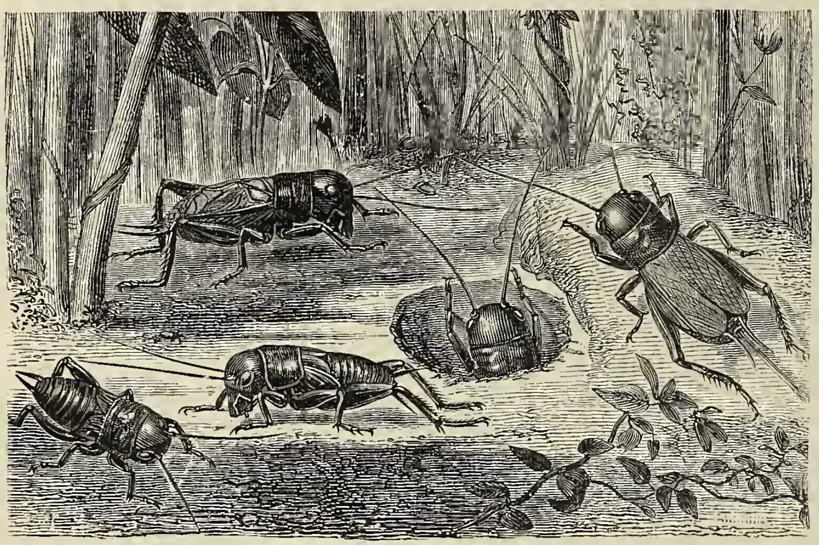
The most striking character of the present tribe—namely, the adaptation of the hind legs to the purpose of leaping—has been already indicated; they have also a large head, and a large, usually saddle-shaped pronotum; and the wings and elytra are generally well developed, frequently extending far beyond the apex of the abdomen. The males of most of the species possess the faculty of producing loud chirping sounds, but the means by which this is effected vary in the different families.

FAMILY I.—GRYLLIDÆ.

In this family, which includes the well-known Domestic Cricket and its allies, the general form of the body is usually more or less cylindrical; the head is large and prominent, with a pair of elliptical eyes, and with or without ocelli; the antennæ are bristle-shaped; and the organs of the mouth powerful. In the latter the development of the outer lobe of the maxillæ (*galea*) is variable. In some forms the galea is so large as to cover the whole of the inner, or masticatory lobe; in others it is narrow, and merely accompanies the inner lobe. It is interesting to find these peculiarities reflected in the corresponding anterior lobes of the labium. In the types with a large galea, the outer labial lobes are so broad that they nearly meet in the middle line, the two inner lobes

being thus pushed out of sight, and the labium appearing to be two-lobed in front; in those with a slender galea, the four lobes of the labium are visible. The legs of the first pair are sometimes converted into fossorial organs, sometimes adapted only for walking or running; and those of the hind pair are generally less elongated than in the succeeding families; the tarsi are generally of three joints, sometimes fewer. The fore wings, or tegmina, lie horizontally upon the back of the abdomen, covering each other more or less towards the base, and usually have a sort of fold at the outer margin, by which they embrace the sides of the abdomen; the wings, which are ample, can be folded into a very small compass, but the extremity of the anterior part of them, which is often marked off from the rest of the wing, is gathered or twisted into a sort of tail, which projects beyond the tegmina and the end of the abdomen. The wings are rarely wanting. The abdomen itself shows nine distinct dorsal and eight ventral half segments, and at its extremity a pair of long, many-jointed cerci. The females of some genera also possess a long, slender, cylindrical ovipositor, which has a slight swelling at its extremity. A curious fact relating to these insects is that the fecundation of the females is effected by the agency of spermatophores of peculiar construction.

As most people are aware, by their experience of our common House Cricket, the males of these animals are endowed with an uncommon power of noise-making. The stridulation in the case of all the musical species of this family is effected by the rubbing of the tegmina over one another, in a manner so well described by Professor Westwood, that we cannot do better than borrow his words. He says—"In the males of the House and Field Crickets, on the internal margin, about one-third of its length from the base, a thickened point is observed, from whence several strong veins diverge, forming an angle from this point. The strongest of these veins, which runs towards the base of the left wing-cover, is found on the under side to be regularly notched transversely, like a file; when the wing-covers are closed, this oblique base of the wing-cover lies upon the upper surface of the corresponding part of the right wing-cover; and when a tremulous motion is imparted to the wing-covers, this bar rubs against the corresponding bar of the right wing-cover, and thus produces a vibration, which is communicated to the other parts of the wing-covers, which, being divided into a number of irregular spaces, have each a distinct vibration, and produce a separate sound," the combination of which produces the well-known stridulation. During this operation the wing-covers of the male Cricket are considerably raised, and the insect presents a very remarkable appearance.



METAMORPHOSES OF GRYLLUS CAMPESTRIS.

The members of this family are not very numerous, but they occur in all the warmer and temperate parts of the earth; and although in hot countries the species are certainly more numerous, they are not generally distinguished from their relatives living in colder zones by larger size or finer colours. In fact, as the species are all more or less subterranean in their habits, and nocturnal in their activity, brilliant colouring is not to be expected in them, and they generally exhibit various shades of brown merging into absolute blackness, but some species show brownish-red or orange patches upon their tegmina. They appear to be tolerably omnivorous, feeding both upon animal and vegetable substances, although usually showing a preference for the former; and the gizzard is well

developed, and shows a remarkable internal armature of chitinous pieces. The Crickets fly freely at night, but their saltatorial powers are inferior to those of the other members of the tribe.

Although most of the species reside in the ground, in burrows and cavities which they dig out for themselves, they do not all possess special fossorial organs; and the family is divided into two groups, according as the fore legs are constructed for walking or digging. Our well-known common House Cricket (*Gryllus domesticus*) belongs to the former section, although it burrows freely by means of its strong mandibles into the mortar between the bricks of fireplaces, ovens, &c. Living as they do in the immediate vicinity of the fire, the House Crickets seem to be independent of the changes of the seasons, and may usually be found of all ages at all periods of the year. During hot summer weather, however, they often make their way out of doors, and even in London their chirp may be heard at night, proceeding apparently from the house-tops. A nearly-allied British species is the Field Cricket (*Gryllus campestris*), which is rather larger than the House Cricket, and of a black colour, with the base of the tegmina yellow. It is a comparatively rare, or rather very local species in England, but abounds in Southern Europe. It makes burrows from six inches to a foot in depth in sunny, sandy places, using its mandibles in the operation. The insect sits in the mouth of its burrow on the look-out for passing insects, which constitute the greater part of its diet. Its chirping is much louder than that of the House Cricket, but it is particularly shy and timid, retreating to the bottom of its burrow at the least suspicion of danger. The female is said to lay about 300 large white eggs, which she deposits in the ground in a mass, glued together and to the side of the burrow by a sticky secretion. The larvæ are hatched about the end of July, and remain in the larva state through the winter. A third British species is the Wood Cricket (*Nemobius sylvestris*), which is much smaller than either of the preceding, and in which the hind wings are rudimentary. It is found abundantly among dead leaves in woods, in France and other parts of the continent, but is rare and local in this country. A still more remarkable species, which may be called the Ants' nest Cricket (*Myrmecophila acervorum*), has neither tegmina nor wings, and in the broadly oval form of the body more resembles a minute Cockroach than a Cricket, a similarity which is increased by the partial concealment of the head beneath the front of the prothorax. It has, however, very strongly developed leaping posterior legs, which it uses in case of need with great effect. This curious little insect is found in France, Germany, and other parts of Europe in Ants' nests, or associated with Ants under stones. The ovipositor is short, and forked at the end.

Most of the species of this first division of the family agree in general characters with the common House Crickets and Field Crickets. They have ambulatory front legs, the females have an ovipositor, and the ocelli are usually deficient. In the second group, the members of which are generally more exclusively subterranean in their habits, living habitually, like the Mole, in galleries and chambers which they dig out in the ground, not only are the front legs converted into special digging organs, but the females have no ovipositor, and the crown of the head has generally two or three ocelli. Their organisation is in many respects very singular, and it is remarkable that they are as widely distributed over the earth's surface as their more normally constructed relatives. Our British Mole Cricket (*Gryllotalpa vulgaris*), which may be taken as a type of the whole group, is a large robust insect over an inch and a half in length, of a dark brown colour, with a very large ovate prothorax, and short, irregularly oval tegmina, beyond which and the apex of the abdomen the wings extend far when folded up. In the character of the fore legs, the insect presents a singular analogy with the Moles. These limbs are very stout, and articulated in such a manner that they are thrown out from the sides of the prothorax in the most convenient position for digging, and the tibiæ, which constitute the actual digging parts, are flattened transversely to the axis of the body, triangular in form, and terminated by four finger-like processes. The tarsi are inserted near the end of the outer margin of the tibiæ, and are short and stout. Owing to the great amount of force necessary to work these implements, the muscles connected with them are very greatly developed, and this explains the large size of the prothorax in which they are contained, and which also possesses a remarkable internal framework of processes for the attachment of these muscles. The insect in burrowing is said to exert a force equal to two or three pounds. Like the Mole, it passes along close beneath the surface of the ground, and often raises a small ridge as it advances. It frequents gardens, especially near the banks of canals and other pieces of water, and also moist meadows, and is described as frequently causing

considerable damage to vegetation by cutting through the roots of plants which come in its way, but apparently not for food, as, although it will consume vegetable substances, its diet consists chiefly of underground insects and worms. The Mole Cricket flies occasionally in an irregular, undulating course in the evening, and its stridulation produces a dull, jarring note, which has been compared to that of the Goatsucker. The eggs, to the number of 200 or 300, are deposited in a chamber of considerable size, and enclosed in a sort of cocoon-like envelope; the larvæ, when first hatched, are white, and they are said to be three years in arriving at maturity.

THE MOLE CRICKET.

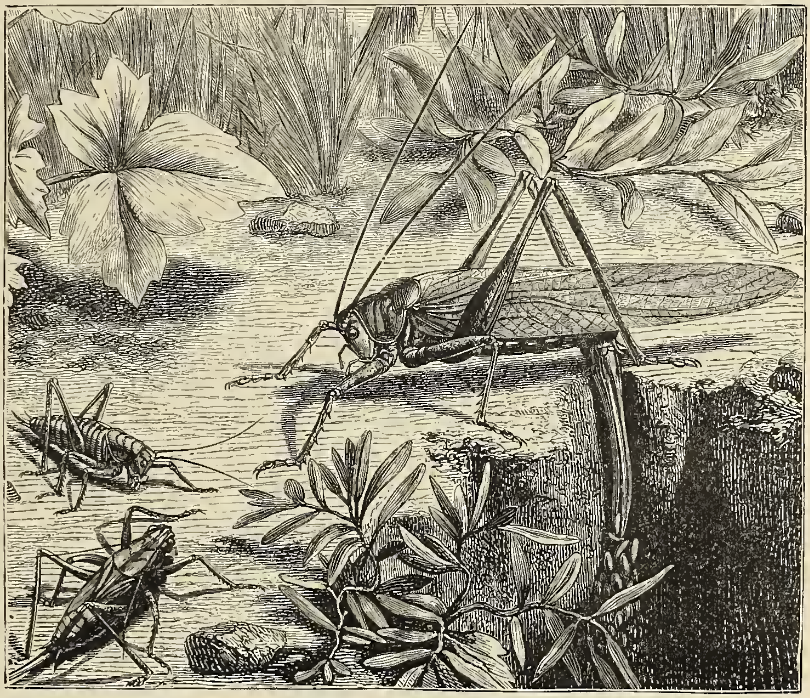
A considerable number of species closely agreeing with the preceding in structure and habits are found in all parts of the world, but the group also includes some which depart rather widely from the common Mole Cricket. One very singular form, described as *Cylindrodes Campbelli*, inhabits Melville Island, on the north coast of Australia. It is about two inches and a half long, and quite cylindrical, with the prothorax forming a third of the total length of the body, with exceedingly short legs, which can be lodged in cavities of the sides of the body, and with two-jointed tarsi. This insect burrows into the stems of plants, and causes them to wither. A true *Gryllotalpa* (*G. didactyla*), inhabiting South America and the West Indies, has often done much damage to the sugar-canes in the same fashion. In some curious little species forming the genera *Tridactylus* and *Rhipipteryx* there are no tarsi on the hinder legs, their place being taken by two or more pointed, movable appendages. One species of *Tridactylus* (*T. variegatus*) occurs in the south of Europe, and burrows in the sand on the banks of rivers. The species of *Rhipipteryx* are from Brazil and Guiana.

FAMILY II.—LOCUSTIDÆ.

Linnæus referred the whole of the Saltatorial Orthoptera to his genus *Gryllus*, which he divided into sub-genera, and gave to each of these an appropriate name. His sub-genus *Locusta* included the species of the following family, among which the true Locusts find their place; but, unfortunately, Fabricius, when forming these groups into separate genera, thought fit to apply the name of *Locusta* to the genus containing the species constituting the present family, and in this course he has been since followed by the majority of entomologists. It is now too late, and would give rise to many embarrassing questions, to revert to the more sensible nomenclature of Linnæus, and we must continue to regard the insects, to which in common parlance the name of Locusts is applied, as not belonging to the family Locustidæ.

The insects so denominated by entomologists present a very considerable variety of form and character, but, like the rest of the Saltatoria, they have a large head, placed vertically in front of the prothorax, and a mouth furnished with powerful jaws. The ocelli are almost always wanting; the antennæ are very long, thin, and bristle-shaped; the labrum is nearly circular, and the inner lobes

of the labium are very narrow, and usually displaced by the enlarged outer lobes; the prothorax is saddle-shaped; the hind legs are usually much elongated; and the tarsi are four-jointed. The two pairs of wings are almost always developed, and they are placed in repose almost perpendicularly on the sides of the body, which they generally exceed in length; the tegmina overlie each other only by a small portion of the inner margin towards the base, and here in the males are situated the stridulating organs, consisting of a peculiar talc-like plate, surrounded by elevated chitinous ridges in the right, and a corresponding space with strong veins on the under surface of the left wing-cover, which overlies the other, and by the friction of these parts a loud chirping is produced. The dorsal surface of the abdomen usually shows the whole of the eleven segments composing that part of the body—at any rate, in the females—which are also furnished with a long, sabre-like ovipositor; in both sexes we find at the end of the abdomen a pair of unjointed appendages. (Fig. 2, p. 282, Vol. V.)



LOCUSTA VIRIDISSIMA AND ITS METAMORPHOSES.

The Locustidæ not only possess a very considerable power of making a noise in the world, but they are also among the comparatively few insects in which a special organ for the perception of sounds appears to exist. The supposed auditory organs in these animals consist of a pair of apertures situated at the base of each anterior tibia; these are closed by tense membranes, between which the main trachea of the limb is dilated into a vesicular form, whilst at the same point a nerve originating from the first thoracic ganglion terminates in a swelling, which gives off a set of peculiar nerve elements, enclosed in small transparent vesicles.

In temperate climates, the adult Locustidæ make their appearance late in the summer or in the autumn; some of them live among herbage on the ground, but the majority frequent trees and bushes. They feed chiefly upon other insects and their larvæ, although vegetable matters appear to form part of their diet. The gizzard is always present, although less highly developed than in the Crickets. Although most of the species are abundantly provided with wings, they do not seem to fly readily, but make use of their wings more after the fashion of a parachute, to support them in the air when making what may be denominated long leaps. The females deposit their eggs in light soil by means of the long ovipositor, which is pushed down into the ground, and then allows the eggs to pass out one by one by the separation of its two valves.

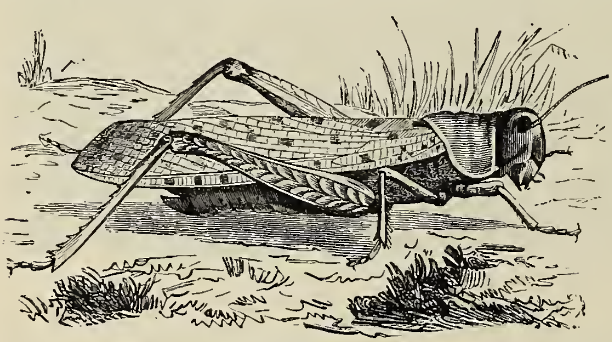
The Locustidæ form a much more extensive family than the Gryllidæ, and they are also very widely distributed, although they are more especially inhabitants of the warmer regions of the earth's surface. In hot countries, indeed, the species are not only much more numerous, but for the most part larger and finer than in temperate climates, although some of the European species are of considerable size. Thus the Great Green Grasshopper—*Locusta viridissima*, as it is called—measures over an inch long in the body; and another European and British form, the *Decticus*

verrucivorus, is of the same length. The former insect is found in many parts of the country in meadows, but it also goes freely upon trees and shrubs; the latter is more particularly a ground-loving species. It receives its name from the custom prevailing among the Swedish peasants of making it bite their warts. The insect, in common with many other Grasshoppers, when at all roughly handled, emits from the mouth a brownish fluid which is said to possess acrid qualities, and the introduction of this into the warts is supposed to cause their disappearance.

The forehead in most species of this family is more or less prominent, but in those of the genus *Conocephalus* this part is produced into a conical process, which projects forward between the antennæ; and in *Copiphora* it forms a very pointed cone which stands up perpendicularly from the head. The females in the last-named genus, the species of which inhabit South America, are remarkable for the length of the ovipositor; in *Copiphora cornuta*, the body is about one inch and a quarter, and the ovipositor two inches long. The general colour of the species, especially of those which live upon trees and shrubs, is green, which renders their detection in their leafy abode very difficult, but in certain tropical genera (such as *Phyllophora* and *Phylloptera*), this difficulty is increased by the form of the wing-cases, which are broad and flat, placed very nearly perpendicularly upon the sides of the body, and traversed by a strong median vein, from which other smaller veins appear to spring after the fashion of the veins of a leaf. The resemblance to particular leaves is so striking that the species are named from it, and we have *Phylloptera laurifolia*, *P. myrtifolia*, *Pseudophyllus neriifolius*, &c. These are all tropical species.

FAMILY III.—ACRIDIIDÆ.

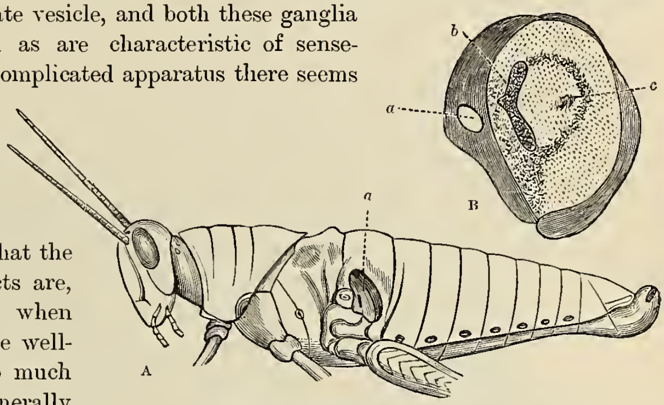
This family, which includes the common Grasshoppers and true Locusts, is easily distinguished from both the preceding by the character of the antennæ, these organs being short, less than half the length of the body, generally thread-like, or even more or less thickened towards the tip. The insects are generally of a stouter form than the Locustidæ, and have the body compressed at the sides. The head is similar in its general character to that of the Locustidæ, but it has almost always three ocelli upon the forehead; the organs of the mouth, especially the mandibles, are strong; the labrum is very large and notched in the middle; and the inner lobes of the labium are much reduced in size and concealed by the outer ones. The pronotum usually shows three longitudinal ridges, and is more or less produced behind; the tegmina are narrow and roof-like, and those of the males contain no special stridulating organs, the well-known chirping of these insects being produced by a different arrangement; the hind legs are elongated; the tarsi are of three joints; and there is no projecting ovipositor in the females.



MIGRATORY LOCUST (*Œdipoda migratoria*).

The song of the male Grasshopper, which must be familiar to every one who has walked through fields in the summer, is produced by the friction of the hinder thighs against the wing-cases. The insect stands upon his four ambulatory legs, and works the hind legs alternately up and down on each side of the body, so that the inside of the thighs passes rapidly over the veins of the wing-cases. Dr. Landois finds towards the lower surface of the inside of each thigh a small elevated ridge, upon which there is a row of minute lancet-shaped teeth, and it is apparently the friction of these little points against the strong veins of the corresponding part of the tegmina that gives origin to the chirping sound. Burmeister says that the females also possess the power of chirping, but this would appear to be a mistake, although they may be observed occasionally performing the same movements of the limbs by which the males produce their sounds; at the same time, it is to be remarked that even the males of some species exercise themselves in the same way without effect so far as our ears are concerned, and yet Colonel Goureau was of opinion that they may be audible to

their companions. The Acridiidæ are provided with peculiar organs to which we may with some confidence ascribe auditory functions. These are two apertures of considerable size situated in the first segment of the abdomen, closed by a membrane stretched upon a chitinous ring, and having upon its inner surface certain chitinous pieces, one of which terminates in a delicate vesicle filled with a transparent fluid, and terminating in two branches. A nerve proceeding from the metathoracic ganglion runs to this apparatus, forms a ganglionic swelling in juxtaposition with the membrane, and another in contact with the delicate vesicle, and both these ganglia give origin to fine nervous rods such as are characteristic of sense-organs. From the structure of this complicated apparatus there seems to be no doubt about its function, which, however, was long a puzzle to entomologists.

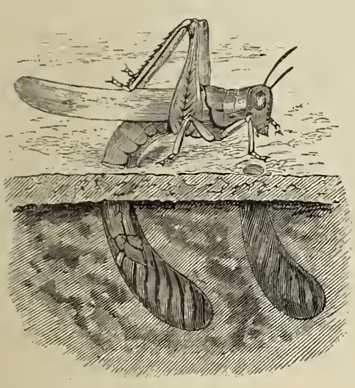


AUDITORY APPARATUS OF GRASSHOPPER.

A, figure showing position of apparatus, *a*, tympanum; B, external surface of apparatus (left outer ear): *a*, opening of the stigma in the raised rim of the tympanum; *b*, the larger horny projection seen through the semi-transparent tympanum; *c*, the smaller horny projection.

The food of the Acridiidæ appears to be exclusively of a vegetable nature, and in accordance with this we find that the gizzard is not developed. The insects are, however, exceedingly voracious, and when they occur in great numbers, as in the well-known invasions of Locusts, they do much damage in cultivated ground. They generally possess great leaping powers, and also fly much better than most of the other Saltatoria, although, as a rule, their flights are of short duration. Many of the larger species, however, rise to a considerable height in the air, and fly to greater distances.

As already stated, the female Acridiidæ possess no exserted ovipositors, but they nevertheless deposit their eggs in the ground in regular cavities prepared for their reception, and in the formation of these receptacles the parts homologous with the valves of the ovipositor in the Locustidæ play an important part in conjunction with the pair of organs representing the cerci. The former are hook-like pieces turned downwards, and when the insect is about to deposit her eggs she brings these together and forces them into the surface of the ground at the selected spot, and then, by the strong muscular action of the abdomen, aided by these valves and the superior tails, she gradually forms a hole nearly large enough to contain the whole of her abdomen. During this process the insect stands upon the four front legs, the hind legs being lifted up out of the way, and as the abdomen, when being pushed into the ground under these circumstances, is necessarily somewhat curved, the cavity formed for the eggs is also curved in the same degree. When the receptacle is completed, the eggs are deposited in it, together with a quantity of a peculiar frothy secretion, produced by glands at the apex of the abdomen, which afterwards hardens, and forms a sort of packing for the eggs, enclosing each of them in a separate cell. The eggs, which are of large comparative size, are carefully packed away in their nest in such a manner that the heads of the young larvæ are directed upwards, and these, when hatched, push their way out either through the spongy material, and so up to the entrance of the cavity or directly through the ground.


FEMALE LOCUST DEPOSITING EGGS.
(*After Bulletin of U.S. Entomological Commission.*)

Our British species of this family, although they are able to make the fields vocal during the summer, are not very numerous, nor are they of very large size. On the continent of Europe, however, even in our latitude, several considerably larger species occur, and in warmer regions we find quite gigantic forms, some of the Brazilian *Acridia* reaching seven or eight inches in expanse of wing. The species, whose ravages have given the name of Locust an unenviable notoriety, are not, however, of

such very large size, the females of the best-known Locusts of the Old World being only about two inches long, while the Rocky Mountain Locust (*Caloptenus spretus*) of North America is only about the size of our largest Grasshoppers. In European countries the Migratory Locust (*Œdipoda migratoria*) is the best known, and this sometimes manages to stray as far as Britain. In the south-east of Europe a nearly allied species (*Œdipoda cinerascens*) occurs. These insects are excessively destructive to vegetation when they make their appearance in unusual abundance. They travel more or less in search of nourishment while still in the larval condition, but their great wanderings are performed through the air after they have attained the perfect state. The most extraordinary accounts are on record of the vastness of the swarms of Locusts which every now and then invade particular districts; they are said sometimes absolutely to darken the sun at noon. They clear everything off the surface of the ground as completely as if the place had been visited by fire (whence the name of "Locust" applied to them). They have on several occasions caused disastrous famines in certain countries, and the putrefaction of their bodies *en masse*, especially on the sea-shore, is described as giving origin to most offensive and pestilential effluvia. The range of these destroyers in the Old World stretches from Spain and the south of France in the west, through southern and central Russia to China; south of this boundary the Locusts have repeatedly done much injury to the crops. In America more or less migratory Locusts are described as committing devastations quite up into Canada. In Eastern countries Locusts are commonly eaten.

TRIBE CURSORIA.

The insects forming this tribe are at once distinguished from those of the preceding families by having the hind legs adapted for walking or running and not for leaping; and from those of the next tribe by the veining of the wings, the central point of radiation of the veins being here placed at the root of the wing. By some entomologists they are treated as constituting two or even three separate tribes, each including only a single family, but this course seems to be quite unnecessary.

FAMILY IV.—MANTIDÆ.

The Mantidæ are at once distinguishable from the insects of the two following families by the structure of their fore legs, which are converted into powerful raptorial organs, in correlation with which the prothorax is also generally much elongated. The coxæ of these limbs are inserted far forward on the under surface of the prothorax, and are very long, reaching, in fact, as far as the base of that segment. Attached to them, with the assistance of a well-developed trochanter, are the femora, which are long, generally stout, and deeply furrowed along the under side, the edges of the furrow being garnished with rows of strong spines; the tibiæ which follow are more slender, but are also strongly armed with spines on the under side, and they are hinged on to the end of the femora in such a way that they can shut into the groove which, as already stated, runs along the lower surface of the latter. As the elongated prothorax can be raised into a nearly vertical position, and the coxæ are very freely articulated, it will be seen that these fore limbs constitute most formidable prehensile organs, from which any small animal seized by them would not have the least chance of escaping. The other four legs are much more slender and organised for walking; the tarsi are all five-jointed.

The body in these insects is more or less elongated; the head, which is triangular or heart-shaped, is attached to the thorax by a distinct neck, and set on vertically; the eyes are oval, usually of considerable size, and inflated, and between them on the forehead, behind the insertion of the antennæ, are three ocelli, which are more distinct in the males than in the females. The parts of the mouth are well developed, and the four lobes of the labium are almost equal in size. The antennæ are generally slender and thread-like, and composed of numerous joints, but variable in length.

The tegmina and wings are generally well developed, reaching or passing the extremity of the abdomen, upon which they are placed horizontally, the tegmina lying one over the other. The latter organs have a very distinct marginal area cut off by a strong vein, and from this veins run to the inner margin, and usually give off numerous fine veinlets which traverse the membrane. The wings show the usual fan-like arrangement of veins characteristic of the tribe. The abdomen is usually elongated, wider towards the extremity, and broader in the females than in the males;

sometimes it is enlarged at the sides. There are eight or nine dorsal segments in the males and one less in the females; the extremity of the abdomen in both sexes is furnished with a pair of jointed cerci.

The species of this family, which are generally of considerable size, those of an inch long being comparatively small, are almost entirely inhabitants of the warmer regions of the world, only a few being found in Southern Europe, and these also occur in Africa. The three most abundant European forms, met with not uncommonly in the south of France, are *Empusa pauperata*,

EMPUSA PAUPERATA AND ITS METAMORPHOSES.

with toothed antennæ, which measures from two to two and a half inches in length; *Mantis religiosa*, a species of equal size with simple antennæ; and a smaller species allied to the latter (*Mantis oratoria*). These insects are remarkable enough by their form, but many exotic species are much more curious. A very considerable number have some parts, especially the femora, dilated into leaf-like pieces, often of singular form; in others the prothorax is widened into a broad leaf-like plate, or some portion of the abdomen has its margins dilated in the same fashion. The colours displayed by many species when alive are exceedingly beautiful, especially the very delicate grass-green which is the general colour of a great number. The hinder wings are often very brilliantly coloured, sometimes showing eye-like spots of large size. In certain desert species, such as those forming the genus *Eremophila*, the colours are, on the contrary, exceedingly sober. These last insects reside in the most barren

deserts of Arabia and North Africa, and their colour is exactly the same as that of the sand on which they run about in search of prey.

When thus engaged, the Mantidæ generally move slowly upon their four rather long and slender ambulatory legs, with the prothorax elevated and the fore legs extended, an attitude which has led to a variety of curious conceptions with regard to them on the part of the imaginative inhabitants of southern Europe. From very ancient times it has been believed that these insects would indicate by the gestures of their fore limbs the road that a wanderer ought to take; hence they were called Mantes, or soothsayers. Another view of their nature ascribes a religious signification to the attitudes taken by the insects, and hence they are known as praying or preaching insects, or by other names intimating a belief that they are habitually engaged in praising the Deity; and, according to an old legend, St. Francis Xavier, on seeing a Mantis moving slowly along with its fore legs raised as if in devotion, desired it to sing the praises of God, which it immediately did in a very beautiful canticle. Unfortunately, all these wonderful notions are by no means correct; the Mantis walking solemnly in a devotional attitude is really an exceedingly voracious creature in search of its prey, and the raised fore limbs are merely extended in readiness to seize its victim as soon as its stealthy pace has brought it within striking distance. Once seized, the prey has no chance of escape; the abundant armature of the femora and tibiæ hold very firmly whatever they get the opportunity of clasping. Their power is very great, and they are used, not only for grasping prey, but also in fighting among themselves, when a successful stroke will often take off an adversary's head. They can even draw blood from the fingers of a human assailant, and in all probability when the soothsayer is supposed to be kindly directing some lost child in the way to its home, the attitude suggesting this kind action is really assumed for defensive purposes.

The female Mantidæ deposit their eggs enclosed in peculiar cases which they attach to the twigs and branches of shrubs, to stones, and other objects. These egg-cases, which vary a good deal in form, are usually of a greyish-brown colour, and furrowed transversely, each furrow generally corresponding to a storey of the interior structure, of which there may be as many as twenty, and the largest of these may contain a couple of dozen eggs. Each egg is contained in a sort of cell, formed by a portion of frothy liquid ejected with it from the abdomen of the mother, and thus the central part of the case is occupied by a series of circles of such cells, each cell containing an egg, which is placed in such a manner that the head of the larva when formed will be directed towards the central axis of the case. The larvæ, when hatched, have therefore nothing to do but to make their way straight forward. The outer part of the case consists of a further portion of the same frothy liquid, which is produced as the business of egg-laying goes on, and worked into shape by means of the extremity of the abdomen. The fluid in question is at first nearly transparent, but as it hardens it gradually acquires a darker colour. The young larvæ are attached to the interior of the shell of the egg, which remains in the cell, by means of two slender silken threads which spring from their cerci, and on their first emergence they remain suspended in the air by these threads until the time of their first change of skin, after which they descend to the ground and go in search of food. This would seem to be a provision to ensure their safety during the first few days of their existence.

FAMILY V.—PHASMIDÆ, OR STICK AND LEAF INSECTS.

If many of the Mantidæ are singular looking creatures, the majority of the members of the present family are still more *bizarre* in their appearance. Most of them resemble sticks, either green, growing twigs, or brown and withered branches, and hence the names of Stick-insects and Walking-sticks, commonly applied to them, are very appropriate. Their skeleton-like forms, often dusky colours, and slow, stealthy motions, have given origin to another similitude—they have been likened to ghosts or spectres, an idea upon which the names of the typical genus and of the family are founded.

The Phasmidæ are at once distinguishable from the Mantidæ, to which, however, they are nearly allied, by the construction of the fore legs, which are ordinary walking limbs, not adapted for seizing anything. In fact, all the legs are similar, although not of equal length; the femora and tibiæ are often dilated into foliaceous lobes; the tarsi are all five-jointed, with large arolia between the claws. The head is freely attached to the thorax, and bears a pair of thread-like

antennæ of variable length; the eyes are hemispherical, and the ocelli are either three in number or altogether wanting. The labrum is deeply notched; the mandibles are short and powerful; the maxillæ and labium are formed much as in the Mantidæ, but the outer lobes of the labium are very much larger than the inner ones. A striking contrast to the Mantidæ is found in the prothorax, which is very short; the mesothorax, on the contrary, is elongated, and is indeed the longest of the three thoracic segments. Both tegmina and wings are often absent, either in the females or in both sexes; when developed, the former are short, and only cover a portion of the true wings, which present a remarkable structure. The front or outer portion of each wing, from the base to the apex, is of a leathery texture, resembling that of the tegmina; the membranous hinder portion of the wing shows the usual fan-like arrangement of primary veins, and the whole of this part, when shut up, is concealed beneath the leathery anterior area, which thus acts the part of a supplementary wing-cover. The abdomen shows nine segments on the back, but in the females only seven, and in the males eight rings are recognisable below, and this is due to the circumstance that in the former the last ventral plate but two, and in the latter the last but one, is usually produced so as to conceal the actual apex, which is furnished with a pair of unjointed cerci, sometimes knobbed or leaf-like in their form.

BACILLUS ROSSII.

The eggs of the Phasmidæ are few in number, and are deposited singly, the females carrying them about in the shovel-like process of the seventh abdominal half-ring for some time before quitting them. The eggs are of large size and covered with a horny shell, at one end of which there is a distinct operculum. The sides are variously ornamented with wavy lines, and the general surface is more or less punctured. In the West Indies the hatching of the eggs has been observed to take place in from seventy to one hundred days after their deposition.

The number of species of this family is not very large; by far the greater part of them are inhabitants of the warmer regions of the earth, and they seem to increase in magnitude especially the nearer their home lies to the equator. The species are much more numerous in the eastern than in the western hemisphere, and in both a few species pass into temperate regions. Two occur in the south of Europe, the best-known being Rossi's Stick-insect (*Bacillus Rossii*), a brown wingless form from two inches to two inches and a half in length, found in Italy and the south of France. Some of the tropical species are the largest of insects, a winged Australian species (*Acrophylla titan*) attaining a length of ten inches, whilst an apterous Brazilian species (*Bacteria aurita*) is of equally gigantic dimensions. The general coloration of the species exhibits various shades of brown and

green, but the wings and tegmina are often variegated, and the former sometimes very beautifully coloured.

The Phasmidæ reside chiefly upon trees and bushes, the leaves of which seem to constitute their sole food. They are nocturnal in their habits, resting during the day among the twigs and branches, where their stiff and somewhat ungainly forms may easily lead to their being mistaken for dried portions of the plant. When resting, the fore legs are stretched forward at the sides of the head, for the reception of which the femora are generally bowed out near the base; the other limbs are brought close to the sides of the body, and the whole insect acquires a most unobtrusive appearance. When danger threatens also these insects will stiffen themselves, and counterfeit death. They are said to have very voracious appetites, and sometimes to do mischief to cultivated trees and plants.

Curiously enough, while the majority of the Phasmidæ simulate portions of the woody structure of the plants they frequent, a few species belonging to the East Indian region present a striking resemblance to leaves, so much so, indeed, that they were formerly supposed to be a sort of compound animal and vegetable organism, and even now cases are sometimes made up by the natives of the countries inhabited by these curious creatures, in which Walking-sticks of different sizes are joined together to represent the branches of a tree, while the foliage is composed of a few Walking-leaves stuck on here and there. These Walking-leaves form the genus *Phyllium*, and they constitute one of the most singular of insect types. The head and exposed segments of the thorax form a sort of stalk, behind which the abdomen is greatly dilated in the form of a thin flat plate, nearly covered in the female by a pair of tegmina veined in such a manner that when the two are placed close together they represent a leaf with its mid-rib, and distinct veins running from the mid-rib to the margins, whilst the space between the veins is reticulated so as closely to resemble the parenchymatous portions of the leaf. The male is amply provided with wings, only partially covered by the short tegmina, and has longer antennæ than the female, in which the latter organs are very short and the wings altogether wanting. The femora are also dilated like little leaves, and the same character is presented by the front tibiæ. These insects are of a green colour when alive, which often changes to a yellowish-brown tint after death; hence the best-known species has been described as *Phyllium siccifolium.*

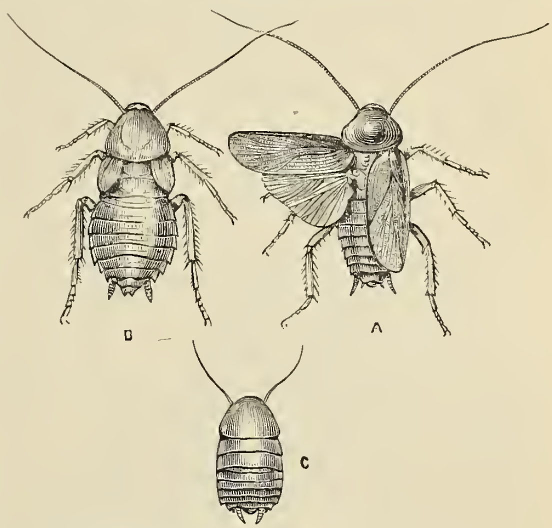
FAMILY VI.—BLATTIDÆ, OR COCKROACHES.

This family includes the numerous species of Cockroaches, or Kakerlaks, one of which, under the name of the Blackbeetle, is but too well known to most housekeepers. They present a very considerable uniformity of general characters, the body being commonly rather flattened and of an oval form, and the head entirely, or almost entirely, concealed beneath the anterior margin of the broad and shield-like prothorax, and so placed that its crown, which rarely bears any ocelli, is directed forward. The eyes are large, and more or less kidney-shaped; the antennæ long, tapering, bristle-like, and composed of many joints; the outer lobes of the labium are considerably larger than the inner ones; the coxæ are approximated, the tibiæ spinous, and the tarsi always five-jointed. The tegmina and wings are generally developed, although sometimes abbreviated, especially in the females. When they attain their full development the tegmina overlie one another at their inner margins, and exhibit a strong vein near the outer margins, from which branches are given off on both sides. The wings show the usual fan-like arrangement of veins. The abdomen presents nine or ten dorsal and from six to eight ventral rings, and at the extremity a pair of jointed cerci.

The Blattidæ are represented in all parts of the world, but most abundantly within the tropics, and especially in America, where also the largest and finest species are to be found. They are active animals, running with considerable rapidity, but their activity is chiefly nocturnal, and during the day they generally remain quietly concealed in some obscure retreat. The introduction of a light into their haunts stops their operations, and generally causes them to run away in confusion to their holes, hence the name of "Lucifugæ" has sometimes been given to them. This applies more particularly to the species which frequent houses, &c. Some of the smaller species, which live in the open air, do not show the same dread of light, although even these are generally active only at night. Their diet consists of both animal and vegetable substances, but the former seem to be

THE EGGS AND IMMATURE AND ADULT FORMS OF *PHYLLIUM SICCIFOLIUM.*

preferred, and the gizzard, although rather small, is thick-walled and well developed. The eggs are deposited by the females in very peculiar hard, horny capsules of an oblong form, rounded at the sides and ends, slightly grooved transversely at the interstices between the contained eggs, and slit along one side, the margins of the slit being finely toothed, with the teeth of one side accurately fitting in between those of the other. The eggs, each of which has its own thin but tough envelope, are placed in a double row within this capsule, arranged side by side in such a way that one extremity of each egg is directed towards the above-mentioned slit. In this manner the escape of the young insect is facilitated, as it has only to push straight forward, and so out of the slit, after softening a sort of cement, with which the closure of the latter is completed. The number of eggs enclosed in these capsules varies considerably in the different species; the common Cockroach of our kitchens places sixteen eggs in each capsule, but those of other species contain thirty or even forty eggs. It will be easily understood that such a capsule as this is very much out of proportion to the size of the parent insect, and the females appear to have some difficulty in getting rid of their burthen. They have been observed to run about for a long time, sometimes even for several weeks, with one end of the capsule projecting from the extremity of the abdomen. The newly-hatched young are of a pale colour, but speedily become darker. They are said to change their skin about six times.



COCKROACHES—MALE (A), FEMALE (B), AND YOUNG (C).

The best-known species is our Common Cockroach, or "Blackbeetle" (*Periplaneta orientalis*), which is not a native of Europe, but is supposed to have been introduced here by commerce from the East. Whatever its origin, however, it has now made a home for itself wherever man dwells. The males have perfect wings and wing-cases, which, however, are shorter than the abdomen; in the females the tegmina are a pair of small, ovate organs placed behind the prothorax, and the wings are quite rudimentary. Another species, which has attained a distribution almost as wide, though not so general, is the American Cockroach (*Periplaneta americana*), a native of the warmer parts of America, whence it has been carried in ships to the ports of nearly all parts of the world. It is a larger and redder species than the common Cockroach, and the tegmina and wings are fully developed, the former passing beyond the extremity of the abdomen. This insect is common on board ship, and may be almost constantly met with in the docks, especially when tropical produce is being landed. It is likely that other species have been similarly transported to new localities, and, indeed, this is known to be the case with a pale species (*Panchlora maderæ*), originally described as a native of Madeira, but now found in Brazil and the East and West Indies, as well as in European ports.

Besides these undoubtedly introduced exotic forms, we have in Europe a few species which appear to be indigenous, and which, both in Britain and on the Continent, live in the open air, in woods, although they sometimes come into houses, and in some localities do considerable mischief. The best known of these may be called the German Cockroach (*Blatta germanica*), an insect about half an inch long, of a pale yellowish colour, with two blackish longitudinal bands on the pronotum. The wings and tegmina are well developed. This species is common in many parts of Europe, and in some places it has proved very troublesome in houses, and especially in breweries and distilleries. The insects are supposed by the Russians to have been introduced into their country from Germany, and thence called "Preussen." In Austria they are thought to have come from Russia, and accordingly denominated "Russen." They have also made their way into other countries. Another species of smaller size, which is common in woods on the continent of Europe, and is found in this

country on whitethorn bushes, makes its way into the dwellings of the Laplanders, and, when it occurs in great numbers, inflicts serious damage upon their stores of provisions. Hence it was described by Linnæus as *Blatta lapponica.* Several other small allied species are met with in this country, but it is to tropical America that we must go in search of the larger and finer forms. The largest of all, the Gigantic Cockroach (*Blabera gigantea*), which measures about three inches in length, is an inhabitant of South America and the West Indies, where it is known as the "Drummer," from its possessing the very inconvenient faculty of producing a noise resembling a sharp knocking with the knuckles against wainscot. This and other large species are said sometimes to devour the extremities of the dead, and even to attack people when asleep. *Blatta gigantea*, however, is a handsome insect, being of a pale yellow colour, like bone, with the head, a nearly square spot on the pronotum, and a sort of dash near the base of the tegmina black or brown. The species of *Phoraspis*, which are also American, are more convex than the ordinary run of Blattidæ, and present no inconsiderable resemblance to some Beetles of the family Cassididæ. One of the best-known species is the *Phoraspis picta*, a black insect rather over half an inch long, with the front margin of the pronotum pale yellow, and a red band upon each of the tegmina. These insects are described as frequenting flowers.

TRIBE EUPLEXOPTERA, OR EARWIGS.

This group, which includes the insects commonly known as Earwigs, is one that has always been a trouble to systematic entomologists. Placed with the Beetles by Linnæus, the Earwigs were speedily removed to a more natural position, side by side with the forms that we have grouped together as Orthoptera Genuina, whilst Leach and Kirby separated them as a distinct order, to which Westwood applied the very appropriate name of Euplexoptera. There can be no question, however, about their belonging to the order Orthoptera as here adopted, nor as to their being most nearly allied to the true Orthoptera, but the opinions of entomologists are divided upon the question of treating the group as a tribe of the latter, or as a distinct group of equal value. After much hesitation we have preferred adopting the former course. They must be regarded as forming a sort of side group, allied to the Phasmidæ and Blattidæ.

The distinctive character of the group is found in the structure of the wings, both pairs of which are developed in all but a few species. The anterior pair (*tegmina*) are of a horny or leathery consistence, but always very much shorter than the abdomen, laid horizontally upon the back, and meeting in the middle line by a straight suture. The hind wings, on the contrary, are of large size, and composed of a very delicate membrane, with the exception of the basal portion of ths anterior margin, which is leathery or parchment-like, terminating at some distance from the base in a piece of somewhat firmer texture. From this point start a series of fine veins, which radiate in all directions to the nearly semicircular margin of the wing, from which another set of veins starts, running in the spaces between the former towards the same centre, but without reaching it. All round the hinder part of the wing, from its base to its apex, runs another vein nearly parallel to the semicircular margin, and intersecting the whole of the radiating veins, and within this the latter all show a slightly thickened portion. When folded in repose, the wings, nothwithstanding their ample size, are completely packed away beneath the short tegmina, and the mode in which this is managed is as follows:—the wing folds up like a fan in the direction of the radiating veins, and it is further bent up from the end of the anterior basal leathery piece, and again folded down through the portion where the radiating veins are thickened, and when these processes are completed the wing can be comfortably concealed beneath the somewhat scanty covering furnished by the tegmina, the only part left out being the stout tip of the leathery basal piece, which nearly always projects more or less, and, to some extent, supplements the tegmina. The wings are deficient in a few species, and some of these are also destitute of the tegmina, but in these cases the insects present other characters which sufficiently indicate the group to which they belong. The tribe contains only a single family.

FAMILY VII.—FORFICULIDÆ.

The insects of this family present a great uniformity of structure, so that any common species may serve as a type of the whole. They have a freely projecting head, united to the prothorax by a short neck; the eyes are small and round, and there are no ocelli; the lobes of the labium are

united in pairs, so that there are only two of them; and the antennæ are thread-like, and composed of from twelve to forty joints. The characters of the wings have been already described. The tarsi are of three joints. The abdomen is considerably elongated, usually a little inclined behind, and composed of nine segments, of which, however, the seventh and eighth in the females are reduced in size, and concealed by the sixth; at the extremity, in place of the cerci present in most of the preceding families, there are two large, curved horny pieces forming a pair of forceps, which often attain formidable dimensions, especially in the males.

The exposed abdominal segments are horny on both surfaces, as in the Brachelytrous Beetles, to which these insects have a certain analogical resemblance. In both groups the elongated abdomen possesses considerable mobility, and is often used to help in packing the wings away beneath the wing-cases.

COMMON EARWIGS.

The Earwigs are, for the most part, crepuscular or nocturnal insects, concealing themselves during the day in crevices, under the bark of old trees, or in the ground, under stones. Their food consists almost entirely of vegetable matters, and they are particularly fond of the petals and other parts of flowers, and of the juices of ripe fruit. In consequence of these predilections they are by no means regarded with favour by gardeners, whose choicest productions they often damage and destroy; in fact, without adopting some means of keeping down the number of these little enemies of his the labours of the gardener would often meet with very imperfect success. The lucifugous habits of the insects, which prompt them to hide themselves as soon as they are exposed to the light, suggest what is perhaps the most successful mode of dealing with them, namely, the placing in the immediate vicinity of the scene of their nocturnal depredations of convenient shelters, such as lobster's claws, reversed flower pots, or portions of reeds, into which the Earwigs creep to avoid the light, and from which they are easily dislodged and then destroyed. This same habit of creeping into holes has no doubt given origin to the name of Earwig, and the corresponding names applied to the insects in many languages. It is quite likely that they may often have sheltered themselves in the ears of persons sleeping in the open air, and such occurrences would easily suggest the idea that they went there for some felonious purpose. The old-fashioned belief that they could in this way penetrate to the brain has, of course, no foundation.

The female Earwig deposits her eggs under a stone in some cavity in the ground, often dug out

by her own labour. She afterwards watches over them with great solicitude, collecting them together if accidentally scattered, and moving them from place to place so as to keep them in favourable conditions as to moisture, &c., although there does not seem to be any foundation for the belief that she actually incubates them after the fashion of a bird. Even after the young are hatched the mother does not desert them, and the little creatures are described as taking refuge under the body of their mother, like chickens under a hen.

The species of Earwigs, which are generally of a yellowish, or lighter or darker brown colour, are tolerably numerous, and widely distributed over the surface of the earth. The tropical regions can hardly claim the same predominance over more temperate climates as regards either the number or the size of the species that we have seen in other families. The largest European species (*Forficesila gigantea*), which is an inhabitant of some parts of England, measures about an inch in length of body, and these dimensions are not greatly surpassed by the exotic species, although some of the latter display much longer forceps than this insect can boast. Our Common Earwig (*Forficula auricularia*) is found not only all over Europe, but apparently throughout the greater part of the Eastern Hemisphere, whether native or as an introduced species, it is impossible to say. Another British species, the Little Earwig (*Labia minor*), is also of very wide distribution on this side of the water, and is said to occur in North America. This insect frequents manure-heaps and hot-beds. It often flies in the afternoon in hot weather, like the little Brachelytrous Beetles with which it is found associated. The apterous species forming the genus *Chelidura*, in which the wings are altogether wanting, and the tegmina also are rudimentary, are chiefly inhabitants of the mountainous parts of southern Europe.

SUB-ORDER II.—PSEUDONEUROPTERA.

In this second sub-order we group together a series of insects which present greater divergence of character than those referred to the Orthoptera Genuina—they are, in fact, the forms which used to be placed among the Neuroptera, but which have been separated from that group in consequence of the imperfect nature of their metamorphosis. As in the Neuroptera, however, the wings, when present, are of a membranous texture, and generally traversed by reticulated veins, and hence the name Pseudoneuroptera, though not a good one, is to some extent appropriate. In the structure of the mouth, in the very general presence of jointed styles or filaments at the extremity of the abdomen, as in the character of the metamorphosis, these insects certainly approach the true Orthoptera, and their first group is in many respects nearly allied to the Cockroaches.

TRIBE SOCIALIA.

This first tribe of the Pseudoneuroptera, as already stated in the table (p. 121), is distinguished by having four equal membranous wings, in which, however, the costal and subcostal veins running along the anterior margin are horny, and the space between them usually thickened and opaque, while the hinder, membranous part of the wing is traversed by finer veins, branching from the longitudinal veins that spring from the base of the wing, but rarely shows any cross-veins. These insects are further remarkable from their living in societies, composed of individuals of very different forms, all of which seem to take part in the business of the community, a condition of things which has given origin to the name of White Ants commonly applied to them. They form only a single family.

FAMILY VIII.—TERMITIDÆ, OR WHITE ANTS.

In this remarkable family of insects, the head projects freely in front of the prothorax, and bears a pair of beaded antennæ of from thirteen to twenty joints, two rounded eyes, and two ocelli. The three segments of the thorax are nearly equal in size, and very similar in form; the legs are simple, and terminate in four-jointed tarsi; and the abdomen, which has only a pair of very minute, two-jointed apical styles, is composed of nine distinct segments. The general characters of the wings, which are usually much longer than the body, have already been indicated; these organs are deciduous, falling off, or being pulled off by the insects themselves, after the performance of the so-called nuptial flight. The alliance to the Blattidæ is recognisable in various parts of the insects, but especially in the structure of the mouth, in which the labium very distinctly shows the Orthopterous character, and the galea, or outer lobe of the maxillæ, is a particularly large and important piece.

The character described of the family applies only to the mature males and females, but the societies of White Ants include other individuals which display at least two different sets of characters, but always present those which would seem to point to their being in an imperfect state of development, such as the absence of wings and ocelli. Of these two principal forms some have a large squarish head, with long projecting mandibles, and the prothorax larger than the other thoracic segments. These are called *Soldiers.* The others, called *Workers,* have a small rounded head with concealed mandibles, and, in fact, either are or resemble true larvæ. In both these forms the eyes are wanting. It would appear, however, that in the case of many species, at any rate, the constitution of the colony is more complex, as will be seen further on.

The Termitidæ are almost all inhabitants of the tropics, only a few comparatively small species being found in temperate climates. These species occur in southern Europe, one of which (*Termes lucifugus*) is abundant in some parts of France, and apparently indigenous; another (*T. flavicollis*) is a North African species which has been introduced into the south of France and Portugal; and the third (*T. flavipes*) appears to have been introduced from South America. In warm countries they form immense communities, and, as their appetites appear to be both indiscriminate and insatiable, they do an enormous amount of mischief in the inhabited localities infested by them. It would seem to be impossible to guard against their attacks, as they make their way underground, or in covered passages, until they reach the spot where their instinct tells them that they will find suitable food, when they make their way up into it, without any necessity of exposing themselves. In this way they will attack woodwork of all kinds, including articles of furniture, the substance of which they destroy, leaving untouched a thin outer shell, so that all the strength may be gone out of a wooden construction, while the appearance of solidity still remains. Even ships have occasionally been destroyed or rendered quite unserviceable by the ravages of these insects.

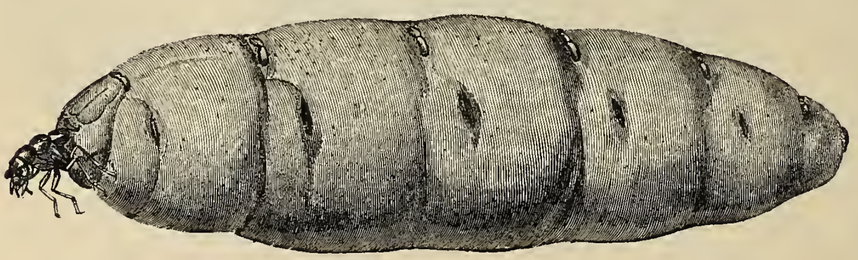
DIFFERENT FORMS OF WHITE ANTS (*Termes lucifugus*).
1, Workman; 2, Soldier; 3, Larva; 4, "Supplementary Female"; 5, Nymph; 6, Male; 7, Female; 8, Gravid Female (*all magnified*).

Their nests are made sometimes in the trunks or among the branches of trees, sometimes upon or in the ground. *Termes lucifugus,* already mentioned, is one of the species which take up their abode in galleries dug in woody material. They infest the trunks of pines and oaks, and will also

attack large posts and piles, in which way they have been exceedingly mischievous in some parts of France, especially in Rochelle, where they attack the piles upon which a great part of the town is built. Many exotic species have similar habits, but they generally seem to affect certain species of trees. The nests made among the branches of trees, as also those attached to fences, and some ground nests, sometimes as big as a hogshead cask, are described by Mr. Hubbard, who observed them in Jamaica, as composed of a brown substance resembling *papier mâché*, probably composed of wood masticated by the insects, and mixed with a viscid saliva. Other ground-living species, such as the celebrated *Termes bellicosus* of South Africa, whose habits were described many years ago by Smeathman, build nests of clay, often of considerable size; thus the dwellings of the South African species just mentioned often attain a height of ten or twelve feet, and are of a conical form, with similarly conical turrets surrounding the main central edifice. These nests soon become covered with vegetation, and their strength is so great that men and large quadrupeds can stand upon them to obtain an elevated look-out point.

We cannot dwell further upon the structure of these remarkable dwellings, all parts of which are occupied by innumerable galleries and chambers, and which usually have a single entrance, from which burrows and galleries are carried in all directions by the inmates. The habits and peculiarities of the latter must now engage our attention.

At a certain season, which differs for the different species, the winged males and females, which have undergone their last change a few weeks before, quit the nest and swarm into the air. After a short flight they descend again to the ground and lose their wings. The males sometimes commence the courtship of their partners during the flight, but more frequently not until after both have come down to the ground again, when the male closely follows the female as she walks about, often even seizing the extremity of her abdomen with his mandibles. It would appear, however, that these manœuvres are strictly of the nature of courtship, in which the male simply seeks to recommend himself to the notice of his intended consort. Unfortunately these sentimental proceedings are only too frequently cut short by the host of enemies—ants, birds, lizards, snakes, toads, and other animals—which flock greedily to the spot. It would seem, from the state of the internal reproductive organs at this time, especially in the males, that there is little likelihood of an impregnation of the female in the air during her short flight, such as takes place in the social Hymenoptera; and, in fact, it seems probable that nothing of the kind occurs until after the bride and her bridegroom have taken up their abode in some hospitable nest, and been adopted as the "king" and "queen" of the community. Their marriage, in fact, is for the remainder of their lives, which last for about a year from this time, and during this period the queen inhabits a large chamber usually placed in the centre of the nest, where she dwells with her selected partner. Occasionally, according to Dr. Fritz Müller, one male may be found in attendance upon two females. After impregnation the ovaries of the queen become exceedingly active, and eggs are developed in them in enormous numbers, so that the abdomen becomes immensely distended, and the chitinous dorsal and ventral plates are widely separated, forming mere patches upon an expanse of soft skin. In this condition the queen is, of course, quite helpless, and her sole business in life is to consume the food furnished to her and to produce eggs, of which she is said sometimes to lay as many as 80,000 in a day. These last are removed by the workers as fast as they are produced, and usually conveyed to the lower part of the nest. The food of the young larvæ, according to Mr. Hubbard, consists of a prepared article stored up in the nest "in the form of very hard and tough rounded masses, evidently composed of comminuted wood." These are scattered through the nests, often in considerable quantities, and



A FEMALE TERMES, FROM THE AFRICAN COAST.

the larvæ attack them from beneath. The young larvæ, according to Mr. Bates, M. Lespès, Dr. Fritz Müller, and others, are all exactly alike, but before they have attained half the length of the full-grown workers, the appearance of the first rudiments of wings serves to distinguish the larvæ from which sexual individuals will originate from those of the soldiers and workers. It is only a little while before the last change of skin that the larvæ of the soldiers and workers can be distinguished. The soldiers are far less numerous than the workers, and their duty would seem to be the protection of the nest, as they make their appearance immediately when it is injured in any way.

M. Lespès, in investigating the history of the French *Termes lucifugus*, was the first to notice the presence in the nests of this species of two forms of so-called "nymphs" (a name here equivalent to pupæ), showing traces of wings in two different conditions. Some of these had long, broad wing-cases covering the anterior part of the abdomen (Fig. 5, p. 137); these give origin to winged male and female insects which swarm from the nests in May or early in June. The "nymphs of the second form" are less numerous, stouter, and heavier than the preceding (Fig. 4, p. 137), and have short rudiments of wings placed on the sides of the thorax. These were found to continue in the nest after the emergence of the winged insects produced from the first form, but their ultimate fate was only guessed at by M. Lespès. According to Dr. Fritz Müller, from whose valuable paper on the Termites we have here largely borrowed, these so-called nymphs, of which he recognizes two forms, are really perfect sexual insects, which he names "supplementary" males and females, regarding them as taking the place of the true "king" and "queen" in the event of such individuals failing to reach the nest. The following table given by Dr. Fritz Müller will make this complex business more intelligible.

1. Youngest larvæ.

2. Larvæ of the asexual forms.		3. Larvæ of the sexual forms.	
4. Larvæ of the Soldiers.	5. Larvæ of the Workers.	8. Nymphs of the first form (Fig. 5).	9. Nymphs of the second form (Fig. 4).
6. Soldiers.	7. Workers.	10. Winged animals.	
		11. King and Queen.	12. Supplementary males and females.

In proof of the reproductive function of the supplementary females at any rate, Dr. Fritz Müller records his having found in the central mass of a White Ant's nest, instead of a royal chamber containing a queen and her consort, a series of irregular passages, in which he discovered thirty-one supplementary females crowded together here and there in groups of five or six, and accompanied by a single male, with large black eyes and the stumps of wings that had been fully developed. Abundance of eggs were found in the neighbourhood of this chamber. Dr. Müller witnessed the production of eggs by the supplementary females, and there was no queen in the nest, and hence, as our author says, instead of a royal palace in which a king was living in decent matrimony with a worthy consort, he had come upon a harem in which a Sultan was disporting himself in the midst of numerous concubines. Considering the immense number of winged individuals which are given off to almost certain destruction by every large community of Termites, and the existence of these wingless reproductive forms, Dr. Fritz Müller inquires what may be the purpose of such an apparent waste of the energies of the community, and finds it in the doctrine insisted upon with so much cogency by Mr. Darwin, of the advantage of cross fertilisation to both plants and animals. The flight into the world of the winged individuals will bring the males and females emerging from different nests together, and thus facilitate inter-crossing, and he finds a confirmation of this view in the fact, already observed by Lespès, that the "nymphs of the second form" usually die off some little time after the swarming of the winged individuals, and the probable entrance into the nest of a new royal pair.

TRIBE CORRODENTIA.

The name of Corrodentia was given by Burmeister to a group in which he included the insects next to be described, together with the White Ants, but later entomologists have separated the latter and retained the name for the former types. These insects have membranous wings with few

and simple veins, of which the hinder pair are not folded in repose; the front of the labium shows only two lobes; and the tarsi have two or three joints. The tribe includes two families.

FAMILY IX.—EMBIIDÆ.

This family consists of a small number of almost exclusively exotic species, which were originally regarded as forming a somewhat aberrant portion of the preceding family. Their fore and hind wings are narrow, and alike in form, size, and venation, the veins being parallel, or rather gently divergent, and simple, except that in some species there are cross veinlets at right angles between some of the veins towards the costal margin. In general form these insects have some resemblance to the Termites, but still more to the insects of the next family but one (*Perlidæ*), to which they would seem to be most nearly related. They have a large free head, with a pair of small eyes and a pair of beaded antennæ, but no ocelli; the prothorax is rather small and narrowed in front, and the other two segments larger and about equal in size; the legs are stout; and the abdomen is rather slender, of eight or nine segments, and terminated by a pair of two-jointed cerci. The maxillary palpi have five, and the labial, when present, three joints.

The species of this curious family are, as already stated, chiefly inhabitants of warm regions. They are found in Africa up to the shores of the Mediterranean, in Persia and India, and in South and Central America. None are yet recorded from Australia, but two species seem to occur in Southern Europe, namely, *Embia Solieri* in the south of France, and a species, probably identical with the Egyptian *E. Savignyi*, in Greece. Of their habits very little is known with certainty. The perfect insects of *Embia mauritanica* have been described as living in company on tall herbage, upon which they run with agility, but seem averse to make use of their wings. The larvæ are found under stones, where they reside in silken cases formed by themselves. M. Lucas says that they are carnivorous, and that the silken webs serve to capture insects upon which the larvæ feed; but great doubt is thrown upon this statement by Mr. McLachlan, who has described a species (*Oligotoma Michaeli*) the larvæ of which had apparently injured the roots of an Indian orchid in a hothouse near London, and were actually found to gnaw the roots when confined with them in a box.

FAMILY X.—PSOCIDÆ.

This is a family of small insects also with simply veined wings, but differing from the preceding in having the hind wings considerably smaller than the anterior pair. In some forms the wings are wanting. They have a rather large head, with the forehead inflated, and bearing a pair of long tapering antennæ, composed of from eight to about fifteen joints. The maxillary palpi are four-jointed, the labium bears no palpi, and the anterior wings show a large horny stigma on their costal margin.

The wings are fully developed in the great majority of the species, which also have three ocelli on the crown of the head, and tarsi composed of two joints. They are found upon the trunks of trees, old palings, walls, &c., in fact, in all those situations where lichens and mosses grow most luxuriantly, and it is upon these and other low forms of vegetation that they probably feed, although they may diversify their diet by consuming the still more minute animals that are to be met with in such places. They are active in their movements, and generally appear in the perfect state towards the end of the summer or in the early autumn. The females deposit their eggs in small groups upon the under surface of leaves, and cover them with a web of fine threads, which they are said to spin from some part of the mouth. The known species, which are not very numerous, are chiefly from the temperate parts of the Old World. Besides the winged species of *Psocus*, and one or two allied genera, the family includes some forms which are never known to acquire wings, and these are only too well known to collectors of insects. They live in books and among old damp papers, whence they are often known as Book Lice; they are also among the "mites" which do so much mischief to collections of insects and dried plants. They differ from the preceding in the absence of wings and ocelli, and in having the tarsi three-jointed. The best-known species is called *Atropos pulsatorius*, the specific name referring to an old belief that this feeble little creature was the "Death-watch."

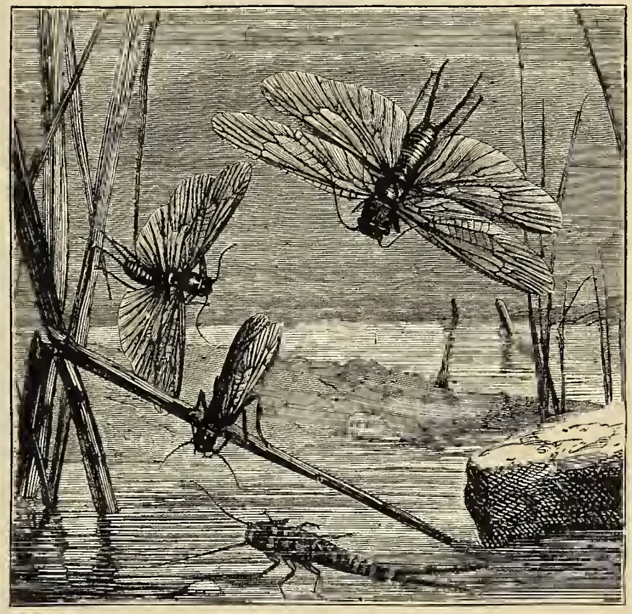
CÆCILIUS FENESTRATUS, MAGNIFIED.

TRIBE PLECOPTERA.

The insects of this tribe are specially distinguished from all the foregoing by the structure of the wings, which have the main longitudinal veins united by branches on the disc of the wings so as to form elongated cells, some of which are usually divided by cross-veins, and beyond which the apical part of the wing is traversed by about double the number of finer veins. The hind wings in nearly all are broader than the anterior pair, owing to the greater development of their hinder area; and in consequence of this they are folded in repose so as closely to wrap the abdomen. The name of the tribe alludes to this character. They form a single family.

FAMILY XI.—PERLIDÆ.

Besides the wing-characters above described, the Perlidæ show a rather elongated body, with a head of large or moderate size, bearing a pair of oval eyes, usually three ocelli, of which, however, the foremost is often very small or even quite rudimentary, and a pair of long, tapering, many-jointed antennæ. Of the parts of the mouth, the mandibles are generally weak and membranous, but sometimes horny and toothed; the maxillæ are rather small, but show distinctly the two lobes, and bear five-jointed palpi; and the labium is cleft in front and furnished with palpi of three joints. Although the wings are well developed, the three segments of the thorax are nearly of equal size; the legs are powerful, and terminated by three-jointed tarsi, of which the last joint is elongated and bears a large arolium between the claws. The abdomen is composed of ten segments, and has at its extremity a pair of jointed filaments, which are generally of considerable length, but sometimes short or quite rudimentary. In the males the wings are often less developed than in the females, a most unusual sexual difference, which applies sometimes to both pairs, sometimes only to the anterior.



PERLA MARGINATA AND ITS PUPA.

The species of this family, which are all of small or moderate size, are not very numerous, and chiefly inhabitants of the temperate regions of both hemispheres. Their larvæ, which closely resemble the perfect insects in general form, except that the prothorax is comparatively smaller, live in running water, and in the larger species are provided with branchial tufts on the under side of the thorax. They creep about upon and under stones, and on the stems of aquatic plants, and are carnivorous in their habits, preying upon smaller aquatic animals, and especially upon the larvæ of the Day Flies belonging to the next family. They also swim pretty freely, partly by means of their widened femora, and partly by undulating movements of the abdomen. The insects are believed to pass several years in their preparatory states, in the last (or pupal) stage of which they acquire the rudiments of wings packed away in cases on the sides of the thorax. When mature they creep up the stem of some plant until they get above the surface of the water, when they rest for a time, until the skin covering the head and thorax splits in the middle line, and the perfect insect creeps forth in a soft state, and with its wings still unexpanded. Even after the full development of the wings, the flight of the imago is slow and of short duration, and the males in many cases cannot fly at all. The perfect insects are generally found resting quietly on plants and other objects on the banks of the streams in which they have passed their earlier stages. The female extrudes her eggs so as to form a little mass adhering to the end of her abdomen, and this is afterwards dropped into the water during one of the short and sluggish flights performed by the parent.

The family is pretty well represented in Britain, where several species are well known to anglers, and supposed to be imitated in those curious productions known as "artificial flies." Thus a rather large brown species, about three-quarters of an inch long (*Perla bicaudata*), is known as the Stone Fly, and appears in April; a much smaller green species (*Chloroperla viridis*), found in May, rejoices in the name of the Yellow Sally, and is also known as the Willow Fly, the latter name being also given, according to Ronald, to a species of *Nemura*, probably *N. variegata*, in which the caudal bristles are rudimentary. The most remarkable circumstance connected with this family is the persistence of branchial tufts in the perfect insects of a small genus, described by the late Mr. Newman under the name of *Pteronarcys*, species of which have occurred in Canada and Siberia. The genus is distinguished by having all the wing-cells divided up by fine cross-veins; and branchial tufts to the number of eight pairs are appended to the stigmata of the thoracic segments, and of the first two segments of the abdomen.

TRIBE SUBULICORNIA.

The insects which we include under this tribe certainly present many points of divergence, and it is chiefly as a matter of convenience that we have retained the group as established by Latreille and adopted by Burmeister. The character referred to in its name is the form of the antennæ, which are short, awl-shaped, and composed of few joints. The wings are membranous, and generally much reticulated; the eyes are large, especially in the males; and the preparatory states, as in the Perlidæ, are passed in the water. The differences presented by these insects are very great, and enable us to distinguish two very well-marked families—the Ephemeridæ, or Day Flies, with very weak or even rudimentary mouths, and the hind wings much smaller than the anterior pair, and the Libellulidæ, or Dragon Flies, with powerful mouths, and wings approximately of equal size.

FAMILY XII.—EPHEMERIDÆ, OR DAY FLIES.

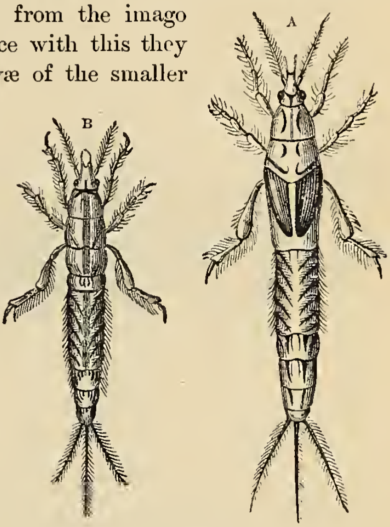
The Ephemeridæ are delicate, elongated, soft-bodied insects, with a moderate or small head, the surface of which, especially in the males, is chiefly occupied by the large compound eyes, between which are placed two or three ocelli. The antennæ, which spring from the forehead below the ocelli, are short and awl-shaped, consisting of two stoutish joints and a minutely-jointed bristle. The parts of the mouth are exceedingly feeble, and, in fact, often membranous in texture, the insect apparently taking no food in the perfect state. The segments of the thorax are very unequal in size, the mesothorax, as might be expected from the great development of the fore wings, being by far the largest; the fore wings are somewhat triangular, and the hinder ones rounded, but sometimes altogether wanting, and the principal veins in both pairs are more or less radiating, although branched, and united by numerous cross-veins, so that the wings are generally minutely reticulated. The legs are generally slender, and are terminated by tarsi composed of four or five joints; the anterior tibiæ and tarsi are excessively elongated in the males. In the long slender abdomen eleven segments may be recognised, the last of which bears two or three very long, bristle-like jointed filaments, and the last but one in the males is furnished with peculiar sexual appendages.

EPHEMERA VULGATA.

These insects, which seem to belong more especially to the temperate climates of the world, are remarkable for the great delicacy of their structure, and for the extreme shortness of their lives in the perfect state, which seems in general scarcely to exceed a day. Hence the name of *Ephemeræ* commonly applied to them. Their emergence, which generally takes place in the evening, is followed by a brief dancing existence on the part of the males, chiefly in the neighbourhood of the waters in which their preparatory stages have been passed, and as the insects are always produced in numbers, and the whole of the members of any given species within a district will make their appearance in the course of a few days, the swarms of Ephemeræ in particular localities are often enormous. On the banks of the canals and slow running rivers of the Netherlands and elsewhere in Europe the air for a few evenings is completely filled with these elegant creatures, and their number is so enormous

that in some places they are collected and used as manure. As their mouths are rudimentary they can take no food in the perfect state, and their sole business is the perpetuation of their kind. For this purpose the eggs are dropped into the water, being set free, in some instances at any rate, by the disruption of the abdomen of the mother.

The development of the larvæ always takes place in the water, and they frequent both streams and still water. The larvæ are not very like the perfect insects, and have a depressed body, long, bristle-shaped antennæ, long plumose caudal bristles, and a series of paired branchial leaflets appended to the sides of the abdominal segments. They differ further from the imago in the powerful development of their mouths, and in accordance with this they appear to be exceedingly predaceous in their habits. The larvæ of the smaller species usually live freely in the water, but those of many of the larger ones burrow most ingeniously into the banks of the stream or pond that they inhabit, making a sort of U-shaped double gallery with two openings to the water, which flows into them, so that the inmate can go in and out without the inconvenience of turning in his abode. If the insects of this family have but a short existence in the perfect state, they make up for this by considerable longevity in their earlier stages, which appear usually to occupy two or three years, during which the changes of skin are very numerous. Sir John Lubbock found that a small two-winged species (*Cloëon dimidiatum*) moulted twenty times in the course of its aquatic existence, and that each moult was associated with greater or less structural changes, until the final condition in which the wings have attained considerable development within their cases. The stage succeeding this is, however, the most extraordinary in the life of the insect. The creature that emerges from the so-called "nymph" is apparently an imago, and is able to use its wings sufficiently to fly to some resting-place, but it is not yet quite mature; all its parts are covered by an exceedingly delicate pilose pellicle, which completely masks the true colour of the perfect insect, and has still to be stripped off before the imago appears. This "subimago," or "pseudimago," as it has been called, attaches itself to various objects on the shore, such as the trunks of trees, palings, the stems and leaves of grasses and other plants, and even the clothes of passers-by; then, after a longer or shorter interval, the outer pellicle is ruptured and the insect comes forth, with brighter wings and much longer caudal bristles, and flies away, leaving the delicate skin still clinging by its claws to the chosen resting-place.



LARVA (A) AND PUPA (B) OF EPHEMERA VULGATA, ENLARGED.

Of British species of this group the best known are the May Flies (*Ephemera vulgata*), of which the subimago is called the Green Drake and the imago the Grey Drake by anglers. These are large species. The little two-winged *Cloëon diptera* and several species of *Baëtis* in which, as in *Cloëon*, there are only two caudal bristles, are also common.

FAMILY XIII.—LIBELLULIDÆ, OR DRAGON FLIES.

In this second family of the Subulicornia, the hind wings, as already stated, are approximately of the same size as the anterior pair, a character which at once serves to distinguish them from the Ephemeridæ. The insects have a large broad head very freely attached to the thorax, and large, convex, prominent eyes, which often meet upon the crown of the head, and have the facets of the upper part larger than those of the lower. Between the eyes are three ocelli, two of which always rest upon the vertex, and the third sometimes upon a bulbous projection of the front of the head, above which originate the short, awl-shaped antennæ, consisting of six or seven joints, of which the first two or three are stouter than the rest. The large labrum conceals the other organs of the mouth, which consist of a pair of strong, horny, toothed mandibles, and a pair of maxillæ, showing a single horny lobe, and a palpus of one joint, unless the palpus be really wanting, and the organ usually so called represent the galea. The mouth is closed below by a broad labium, which is of peculiar construction, the outer lobes being amalgamated with the two-jointed palpi, and the inner lobes either

separated or united into a single piece. The structure of the thorax is also peculiar. The prothorax is small and ring-like, and the meso- and meta-thorax are of large size, and placed almost horizontally one above the other, so that the true back to which the wings are attached is quite behind, and the breast, with the legs, thrown forward towards the head. The wings are closely reticulated, and the legs of moderate length and strength, and terminated by three-jointed tarsi. The abdomen is elongated, sometimes very long and slender, and is composed of eleven segments, of which the last but one bears a pair of unjointed claw-like or leaf-like appendages.

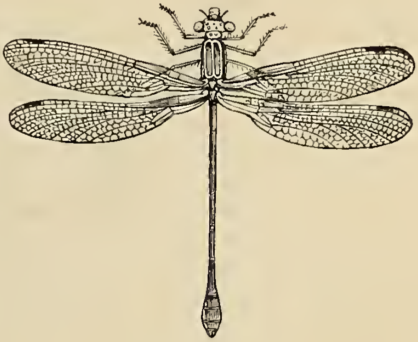
These insects, which are for the most part of moderate or large size, constitute a very numerous group, some fourteen hundred species having been described from all parts of the world. They are numerous and abundant in temperate climates, but become still more so within the tropics, where also the finest species are met with. Nevertheless, the warmer regions have not so much advantage over extra-tropical countries in the case of this group as of some others; some of the European and British species may vie in size and colouring with all but a few of their exotic relatives.

LIBELLULA DEPRESSA.

Their habits are everywhere much the same. Like the Ephemeridæ they are generally found in the vicinity of water, in which element their preparatory stages are passed, but quite unlike those abstemious creatures, they are exceedingly voracious in their habits, continually hawking about upon their long and powerful wings in pursuit of their prey, which consists entirely of weaker insects captured in the air. Thanks to a particularly powerful arrangement of muscles and tendon-like pieces contained in the large thoracic segments which bear the wings, those organs are capable of almost incessant action, and the Dragon Flies may be seen throughout a summer's day continually sweeping about over the surface of some pond or stream, or poising themselves motionless in the air from time to time by excessively rapid vibrations of the wings. They rest at night, and sometimes by day, especially in dull, cloudy weather, upon the twigs of trees and bushes, and the stalks and leaves of grasses and other plants, and it is singular to observe how easily the insect when thus resting escapes observation, notwithstanding its considerable size and often striking coloration. Their courtship is one of the most singular points in their history. The male seizes the female by the neck with the claspers appended to the last abdominal segment but one, and thus united the pair may often be seen in flight. After a time the female curves the end of her abdomen forward until it comes in contact with the second abdominal segment of the male, which is singularly inflated and cleft, and contains an organ by means of which the fertilising male elements are introduced into the proper position for fecundating the eggs; and what renders this arrangement still more singular is, that in the male the ducts leading from the organs secreting the fertilising fluid open near the end of the abdomen in the ninth segment, so that he must, before going in search of his mate, purposely charge the reservoir in the second segment of his abdomen. After the completion of the process, the pair usually separate, but in some instances the male continues to clasp the neck of the female, so as to assist her in flying over the surface of the water in order to deposit her eggs suitably.

In their general form the Libellulidæ present very considerable differences, and in accordance with these we may distinguish three principal groups. In a very great number the head is short and transverse, forming a sort of cylindrical piece, on the two ends of which the eyes are situated, separated by a wide crown on which the ocelli are placed; the abdomen is cylindrical and very slender; and the wings, which are of equal size, are closed together over the back of the abdomen in repose. These, forming the sub-family Agrionides, are the most elegant of all the species, and it is no doubt in allusion to the graceful slenderness of their forms, and to the mode in which they are as it were draped in gauze when their wings are closed, that our French neighbours have bestowed upon the Dragon Flies in general the fanciful name of *Demoiselles*. Several species are exceedingly

abundant in this country. *Agrion puella*, in which the abdomen of the male is banded with azure blue, while that of the female is almost entirely brassy black, is an insect about an inch and a quarter long that occurs almost everywhere; and the beautiful *Callepteryx virgo*, of which the male is steel-blue with a large brown patch with steel-blue lustre on each wing, and the female rather greenish with brownish wings, is to be met with frequently about running waters. Some American species have the abdomen of inordinate length, extending far beyond the closed wings. These form the genera *Megaloprepes* and *Mecistogaster*, species of which attain the length of four or five inches.



AGRION PUELLA.

In a second group, that of the ÆSCHNIDÆ, the abdomen is still cylindrical, but stouter in proportion than in the Agrionides. The head also is large and nearly hemispherical in form, and the eyes are enormous, usually covering the whole upper and lateral surfaces, and meeting on the crown in the middle line. The wings are always extended at the sides of the body. These are large and strong insects, possessing a wonderful power of flight, and several species are common in Europe and Britain. The Great Dragon Fly (*Æschna grandis*) is one of these. It is nearly three inches long, and is of a light rusty brown colour, with a few paler markings. Another is *Gomphus vulgatissimus*, a black insect nearly two inches long, with yellow bands on the thorax and a line of the same colour along the back of the abdomen. Some of the tropical species attain a considerably larger size.

Finally, in the true LIBELLULIDES we find the head, eyes, and wings showing the same general characters as in the last group, but the abdomen is either broad and more or less flattened or comparatively slender, and then triangular in section. In some forms the abdomen shows an approach to the type of the Æschnides, but then recourse may be had to a small character presented by the wings, which have a marked triangular space a little way from the base, and this is alike in both pairs of wings in the latter, but different in the Libellulides. The best-known English species of this group is the *Libellula depressa*, vulgarly known as the Horse Stinger, an insect nearly two inches long, with a rather broad depressed abdomen, which is yellowish-brown with yellow spots on the sides in the female, and coated with a beautiful violet-blue powder in the male. It may be seen almost everywhere hawking about over rivers and ponds.

NYMPH OF LIBELLULA, AND THE PERFECT INSECT EMERGING.

The larvæ of these different forms, although not very closely resembling their parents, nevertheless differ from each other in general form, somewhat after the same fashion as the perfect insects, but all agree in one character, namely, that of being among the most predaceous of the insect inhabitants of the water. The apparatus by which they capture their prey is of the same general nature in all, and consists of a peculiar modification of the labium, which has been called the "mask." In repose the chin-piece is folded back towards the breast, and to its extremity the broad labium is attached by a hinge-joint, and the anterior margin of this bears a pair of forceps-like organs, representing the outer lobes of the labium united with the palpi, and articulated so as to close towards the middle of the labium. Sometimes these terminal pieces are so large as to cover a great part of the face when the labium is retracted; in all cases the labium with its appendages completely closes the

mouth. In seizing a prey it is darted out towards the victim, which is firmly grasped by the apical forceps, and then easily conveyed within reach of the other organs of the mouth.

Besides the difference of form, these larvæ also present important differences in their respiratory apparatus. In the Agrionides the larvæ are always provided with external branchial organs appended to the extremity of the abdomen, sometimes alone, sometimes in conjunction with an internal breathing apparatus similar to that prevailing in the other two groups, which consists of a peculiar arrangement and ramification of tracheæ in the walls of the rectum or terminal portion of the intestine. The water is drawn into and expelled from this by the action of special muscles, and the expulsion is so forcible that the creatures are slowly moved through the water by its recoil. The insects are active and voracious throughout their preparatory stages, in the last of which they show large wing-cases behind the thorax. When full grown they crawl up the stems of some aquatic plant into the open air, and after resting there for a longer or shorter time, the skin splits along the thoracic region, and the perfect insect by degrees struggles out of its investment. The wings, at first, have not attained their full development, but this is soon reached, and the Dragon Fly starts off to continue in the air the same scene of rapine that has characterised its subaqueous existence.

SUB-ORDER III.—PHYSOPODA.

The Physopoda are a curious group of insects, the true position of which has been always doubtful. Some writers place them with the Orthoptera, others with the Rhynchota, and others again in a separate order, side by side with one or other of those just mentioned. We have preferred here to follow Burmeister and those entomologists who have adopted his view of the matter.

These insects have a narrow flattened body, and two pairs of narrow wings, which show few or no veins, but have their margins fringed with longish hairs, whence the name of Thysanoptera (or "fringed wings") was applied to the group by the late Mr. Haliday. In repose these wings lie flat over one another upon the back of the abdomen, leaving the margins of the latter exposed. The head is of a somewhat cylindrical form, and bears a pair of large eyes, a pair of antennæ consisting of eight or nine joints, and three ocelli placed between the eyes. The wings and ocelli are deficient in some species. The mouth is bent back towards the breast, and pointed, so as to remind one of the character of the rostrum in the Homoptera, and still more in the *Notonectæ*, but its structure is very different. Thus the mouth is closed in front by a pointed labrum, behind which is a pair of bristle-like mandibles more or less dilated at the base. Within these again are found two simple maxillæ, bearing palpi of two or three joints; and the whole apparatus is completed by a membranous labium, pointed in front, and furnished with short two-jointed palpi. The legs are of moderate length, or short, and have tarsi of two joints, the second of which bears no claws, but terminates in a bladder-like disc, by means of which the insects adhere to the objects upon which they walk. Hence arises the name of Physopoda, and the action of these little suckers causes the insects to produce a very uncomfortable tickling sensation when they run upon the skin of people's faces.

The Adult Insect. The Larva.

THE LARVA AND IMAGO OF THRIPS CEREALIUM, ENLARGED.

The insects of this group are all small. The ordinary run of species are about one-twelfth of an inch long, many less, and those of an eighth of an inch may be looked upon as large. From this point of view the species of *Idolothrips*, which inhabit Australia, are gigantic, measuring from a quarter to a third of an inch in length. The Physopoda are no doubt abundant in all parts of the world, but comparatively few extra-European species have been recorded. In Europe, however, they are numerous, and may be found throughout the summer upon the leaves and flowers of plants, especially the latter, where they often look like so many black streaks scattered over the bright petals. Many of them, however, are not black, and some seem to copy the colours of their favourite flowers. The larvæ, in all stages, are found in the same situations as the perfect insects, which they

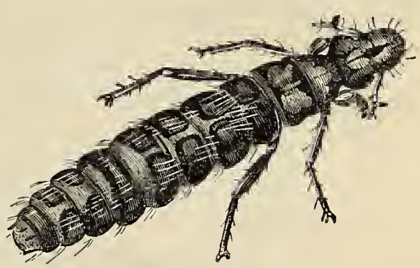
closely resemble in general form and structure, differing chiefly (besides the want of wings in those of the winged species) in greater softness of the skin, in the shortness of the antennæ, and in having agglomerated instead of compound eyes. In the last, or nymph stage, the wings are usually seen in their cases, but the antennæ are turned back upon the head. There is a filmy integument about the joints of the limbs, and the insect is more sluggish than in the larva or perfect state.

Although the mouth, as we have seen, is constructed upon a mandibulate type, the insects appear to use it for suctorial purposes, although the precise mechanism by which it acts does not seem to have been made out. There are two principal groups or families of these insects, in one of which, the TUBULIFERA, the last segment of the abdomen in both sexes forms a little tube; while in the other, the TEREBRANTIA, the females are provided with a regular ovipositor composed of four minute valves concealed in a groove of the last two ventral segments. In the former the antennæ are eight-jointed; the latter usually have nine-jointed antennæ, and they possess the power of jumping by the agency of the abdomen. These insects are generally known to gardeners by the name of the Thrip or Thrips, the latter being the name of the most typical genus. Some of them occasionally prove injurious to cultivated plants. This is especially the case with the Corn Thrips (*Thrips cerealium*), which generally attacks the ears of corn, and when numerous may be mischievous.

SUB-ORDER IV.—MALLOPHAGA.

These insects may be denominated "mandibulate lice," that is to say, both in appearance and general habits they somewhat resemble the true Lice, with which they were formerly arranged, but differ in the possession of biting mouths, and in the diet to which such a structure adapts them. They are small flat insects, with the upper surface more or less horny in its texture; the head is broad and horizontal; the thorax narrow and destitute of all traces of wings; the abdomen usually broad and of nine or ten segments; and the legs short and stout, with tarsi of two joints furnished with one or two claws. The eyes are small and usually simple; the antennæ consist of from three to five joints; and the mouth, which is situated beneath the head, contains a pair of short hooked mandibles, a pair of small maxillæ with or without palpi, and a labium with palpi of two joints.

A great number of these curious little insects have been recorded, and they inhabit all parts of the world, in fact it would seem as if there were few birds at any rate to which no parasite of this group is attached. They live among the hairs of the Mammalia and the feathers of birds, each species of parasite being usually attached particularly to some species or small group of species of these warm-blooded Vertebrates; but unlike the true Lice they do not feed upon the blood of their hosts, but upon the finer hairs and downy feathers. Frequently they occur in considerable numbers, and may then perhaps, to some extent, be injurious.



PHILOPTERUS SELCIFRONS.

Here again two principal families may be distinguished. The PHILOPTERIDÆ have thread-shaped antennæ of three or five joints, and no maxillary palpi. The species with five-jointed antennæ (*Philopterus*, *Nirmus*, *Docophorus*, &c.) infest birds; and those with the antennæ of three joints (*Trichodectes*, &c.) are found upon mammals of various groups. In the second family (LIOTHEIDÆ) the antennæ are clubbed and composed of four joints, and the maxillary palpi are present. Species with distinct labial palpi, and two claws on each tarsus (*Liotheum*, and allied genera), live upon birds; and those with no labial palpi, and with only one claw on each tarsus, on mammals. The common fowl, ducks and geese, game-birds of all kinds, and pigeons are very commonly infested by these parasites, as are also the dog and cat, the sheep and the guinea-pig.

ORDER THYSANURA.

We have now reached the last order referred to the class of true insects, and it is a group of no small interest from a philosophical point of view. The forms composing it are reckoned to present the nearest resemblance to the theoretical progenitors of the Insecta—in fact, Sir John Lubbock hints that they might well be regarded, not as insects at all, but rather as the surviving

and perhaps modified representatives of a group formed by the ancestors of the whole multitude of insect types which we have here attempted to pass in review.

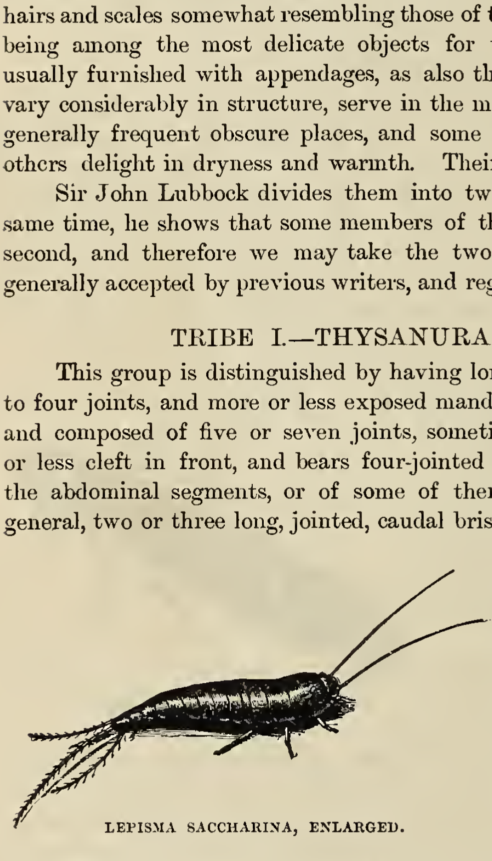
The Thysanura have been considered by different entomologists to form either a distinct order or a section of the Orthoptera, while some writers have even thought that they might rather be united with the next class. Considering this diversity of opinion, and the real peculiarities of organisation from which it springs, it seems best to treat these little creatures as actual members of the class of insects, with which they most nearly agree in structure, but to give them prominence by ranking them as a distinct order. At the same time, while an undoubted close relationship runs through all the members of the order, there is sufficient difference in the groups of which it is composed to render it difficult to formulate a set of characters which shall apply pretty equally to the whole.

One primary character is to be found in the entire absence of wings, and of any metamorphosis; and a second, in the feebleness of the organs of the mouth, which are also generally concealed within the cavity of the head. The eyes, when present, are almost invariably ocelli or simple eyes, either placed singly or aggregated in groups on the sides of the head; true compound eyes occur only in one genus. The body is generally rather soft in texture, and has its surface clothed with peculiar hairs and scales somewhat resembling those of the Lepidoptera, but of course much smaller, some of them being among the most delicate objects for the microscope. The lower surface of the abdomen is usually furnished with appendages, as also the apex of that region in some species, and these, which vary considerably in structure, serve in the majority as saltatorial organs. The members of this order generally frequent obscure places, and some of them show a preference for moist localities, while others delight in dryness and warmth. Their food consists of decaying vegetable matter.

Sir John Lubbock divides them into two orders, the THYSANURA and the COLLEMBOLA. At the same time, he shows that some members of the former group are very nearly related to those of the second, and therefore we may take the two groups, which really agree precisely with the families generally accepted by previous writers, and regard them as forming two great tribes of the same order.

TRIBE I.—THYSANURA GENUINA, OR BRISTLE-TAILS.

This group is distinguished by having long antennæ composed of many joints, tarsi of from two to four joints, and more or less exposed mandibles and maxillæ. The maxillary palpi are often long, and composed of five or seven joints, sometimes shorter, and only two-jointed; the labium is more or less cleft in front, and bears four-jointed palpi; the prothorax is large; and the under surface of the abdominal segments, or of some of them, bears pairs of appendages (rods or tufts), besides, in general, two or three long, jointed, caudal bristles. The body in these insects is almost always clothed with metallic scales, which closely cover the whole surface, and give the creature a beautiful silvery appearance; but, unfortunately, these scales are rubbed off by the lightest touch, and it is very difficult to capture one of these insects without sadly spoiling its beauty. In some respects, especially in the conformation of the organs of the mouth, the more typical members of this tribe, forming the family LEPISMIDÆ, approach most nearly to the Orthoptera, and among the latter the alliance would seem to be closest with the Blattidæ. Of this family a good many species are known, chiefly from different parts of Europe and the neighbouring countries, the largest of them being rather more than half an inch long. *Lepisma saccharina*, a silvery creature like a little fish, is not uncommon in Britain, living in decaying wood, and also frequenting houses, where it commonly takes up its abode in the sash-frames of the windows. It runs rapidly, but does not leap. In the genus *Machilis*, two species of which inhabit this country, the ventral segments are nearly all furnished with paired appendages, and those of the ninth segment are converted into a springing fork homologous with that characteristic of the next tribe. One British species (*M. polypoda*), which is brown with a metallic lustre, is found in woods and dry places; the other (*M. maritima*), a mottled brown species, occurs under stones on rocky shores. These insects are about half an inch long. They have com-

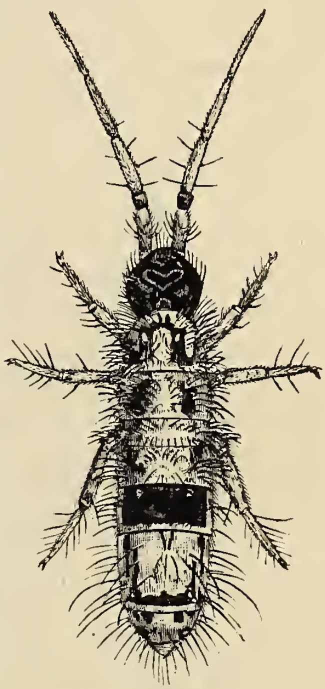


LEPISMA SACCHARINA, ENLARGED.

pound eyes. *Campodea staphylinus*, a small elongated species about a sixth of an inch long, with two caudal bristles, is common in loose, damp ground both in England and on the continent. It has the palpi short, and all the parts of the mouth minute, and is regarded by Sir John Lubbock as a sort of central type, from which many others have been derived. It is the type of the family CAMPODEIDÆ. Both this and the family JAPYGIDÆ show a strong affinity to the second tribe (the Collembola). *Japyx solifugus*, a white species less than half an inch long, is found under stones in different parts of the south of Europe. It is much elongated, and the abdomen terminates in a pair of little horny forceps, closely resembling those of the Earwigs. Another species (*Japyx gigas*), from Cyprus, is the giant of the Thysanura, sometimes measuring more than an inch long.

TRIBE II.—COLLEMBOLA, OR SPRING-TAILS.

The Collembola, which correspond to the family Poduridæ of most authors, have the antennæ comparatively short, and composed only of from four to six joints; the organs of the mouth concealed within the buccal cavity, and destitute of palpi, except a pair of rudimentary organs, which Sir John Lubbock identifies with the maxillary palpi in certain species; the prothorax small; the tarsi of a single joint, and the abdominal appendages represented by a single pair springing from a segment near the apex (the last but one, or the last but two), united at the base to form a springing fork, and bent forward in repose, so as to reach nearly or quite to the head. By the action of this fork, the arms of which are frequently jointed, and furnished with adhesive hairs, the insects thus endowed are enabled to spring to a considerable height in the air, the process being precisely analogous to that by which the common toy frogs are made to jump. In form these insects are sometimes irregularly globose, but more commonly rather elongated, although never presenting the rather elegant, fish-like shape of many of the preceding tribe. Their surface is covered with hairs or scales, or with a mixture of both. The tarsi are terminated by a single curiously-cleft claw. The abdomen consists of six segments, on the ventral surface of the first of which there is a very peculiar organ. This consists of a cleft tubercle, or a short tube divided at the free end into two lobes, from which the animal can protrude two long, delicate tubes, covered with minute glands, by means of which, and of a viscous fluid produced by these curious organs, their fortunate possessors are enabled to adhere with facility to smooth vertical objects upon which they may be walking. According to some writers, there are four pairs of stigmata upon the first four segments, leading into a regular tracheal system; but the existence of the latter is by no means demonstrated in all the forms of this tribe. Sir John Lubbock seems to have detected tracheæ only in one genus examined by him (*Smynthurus*), and he declares that the stigmata leading into these tracheæ are situated upon the under side of the head. This is a most unusual situation for the tracheal openings.



ORCHESELLA CINCTA, ENLARGED.

The Collembola are all small insects, a length of a quarter of an inch being considerably above the average. They are found commonly in loose earth, under decaying leaves in woods, in moss, under the bark of dead trees, and in rotten stumps. They always prefer damp situations. Cold seems to have but little effect upon them; they will recover their activity after being frozen. One species (*Desoria glacialis*) is found enjoying itself upon the Swiss glaciers; and another (*Degeeria nivalis*) occurs upon the surface of snow in many parts of Europe. Some also may be met with hopping about upon the surface of standing water; *Podura aquatica*, a minute blue-black species, is common in such situations in England. *Orchesella cincta*, one of the finest and handsomest species, a quarter of an inch long, distinguished by having a black band on the third segment of the abdomen, is found commonly under dead leaves, and in moss; *Toxocerus plumbeus*, a rather smaller species, is found under logs of wood.

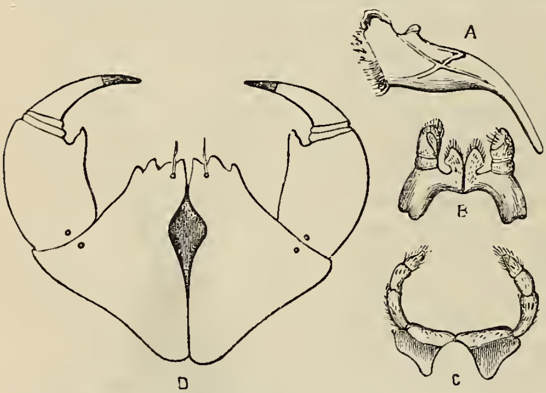
W. S. DALLAS.

CLASS MYRIOPODA.

THE CENTIPEDES AND MILLEPEDES.

Definition of the Class—External Structure—Internal Structure—Reproduction—General Habits—Fossil Forms—Classification—Order CHILOPODA—Structure—Distribution—Habits—Family SCUTIGERIDÆ—Family SCOLOPENDRIDÆ—Centipedes—*Lithobius forficatus*—*Scolopendra cingulata*—*Geophilus*—Phosphorescence—Order CHILOGNATHA—Family JULIDÆ—Millepedes—*Julus sabulosus*—Family POLYDESMIDÆ—Family SIPHONIZANTIA—Family GLOMERIDÆ—Order PAUROPODA—*Pauropus Huxleyi*—Order ONYCHOPHORA—*Peripatus.*

THE Myriopoda, commonly known as Centipedes and Millepedes, form one of the most interesting groups of the whole animal kingdom. In the general structure of the body, which in most of them consists of a considerable number of similar segments, they present a close resemblance to the highest forms of the Vermes, the Annelida, and indeed one type that we must refer to the class (*Peripatus*) would seem to constitute a complete transition between the two classes; whilst, on the other hand, in the organisation of the mouth, and the presence of only a single pair of true jointed antennæ, we find a transition equally complete towards the true Insecta. Some zoologists have dwelt with perhaps undue force upon the analogy between the Myriopoda and the larvæ of insects with a perfect metamorphosis; but too much importance can hardly be ascribed to the fact that the youngest larvæ of some of the Myriopods are furnished only with three pairs of legs, and in other respects much resemble the young of insects with an imperfect metamorphosis, and above all the Collembolous group of the Thysanura.



PARTS OF MOUTH OF A SCOLOPENDRA.
A, Mandible; B, united maxillæ and labium; C, first pair of legs; D, second pair of legs. Enlarged.

The Myriopoda may be defined as Arthropods with a distinct head, and most of the other segments almost precisely similar to one another, with a single pair of antennæ, and nearly always with simple eyes, with no distinct thorax, and without wings, but with limbs attached to all, or nearly all, the segments of the body. The respiration, as in the insects, is effected by means of tracheæ.

The head, as already stated, is a distinct part, and agrees in general with that of the Insecta, bearing a single pair of antennæ, which are almost invariably simple, jointed organs. The organs of vision generally consist of simple eyes (ocelli), which, however, are often closely grouped together on the sides of the head. In one family true compound eyes are present. As in the Insecta also, we find three pairs of jaws represented in the mouth, the mandibles being distinct, while the maxillæ and labium are united to form a sort of lower lip, and are thus deprived of all lateral motion. No palpi are recognisable upon any of these parts. In one of the orders into which the class is divided the limbs of the first two body-segments take part in the formation of the mouth. The segments of the body are nearly alike throughout; they are generally horny, and furnished with a pair of jointed limbs. The number of segments varies greatly in the different groups, and even in the genera, the lowest being ten, the highest about one hundred and sixty. In the Centipedes (Chilopoda) we find a slight difference in the character of the first two segments, of which the dorsal part is suppressed or concealed by the head, while the limbs, as already indicated, take part in the formation of the mouth. In the remaining groups the segments are uniform in their development, except that they may become broader towards the middle of the body. The legs, which are usually short, are attached sometimes at the sides of the ventral plates, sometimes close to the middle line of the lower surface of the body. In the latter case each segment bears two pairs of legs, and it becomes a question whether we should not regard the apparent segments as really formed by an amalgamation of two primitive segments. These limbs consist of six or seven joints, of which the last, except in one singular worm-like type, bears a single claw. If we name these joints in accordance with the nomenclature of the parts of the

limbs in insects, the first three will be the coxa, trochanter, and femur, the fourth and fifth will represent the tibia, as in the Spiders, and the sixth, or sixth and seventh, which usually differ more or less in form from the preceding ones, will form the tarsus.

In their internal structure the Myriopoda closely agree with the insect type. The intestinal canal shows the same parts as in the Insecta, but usually drawn out to a greater length, to correspond with the general elongation of the body, through which it passes nearly in a straight line. A narrow œsophagus gradually expands into a stomach, which, however, is only a widened part of the tube, and this is followed by a straight intestine running to the extremity of the body. As appendages to the intestinal canal, we find from one to three pairs of salivary glands, and one or two pairs of Malpighian vessels, the former opening into the cavity of the mouth, the latter into the intestine not far from its termination. The nervous system of these animals consists of a ventral chain, which shows the same uniformity of general construction that is observed in the larvæ of insects with a perfect metamorphosis, the ganglia corresponding in number with the body-segments, except that in most cases the commissures uniting the successive ganglia are very short, often so short that the central system forms a cord rather than a chain. The ganglia of the first three segments following the head are regularly united into a continuous mass. In the head there is the same nervous ring embracing the œsophagus as in insects, and from it are given off nerves to the antennæ and eyes, the latter of considerable thickness when the organs of vision are greatly developed. In the worm-like genus *Peripatus*, which is placed with the Myriopoda, but in all probability represents a survival of a type intermediate between the Annelida and the Myriopoda, the ventral nervous cords are widely separated.

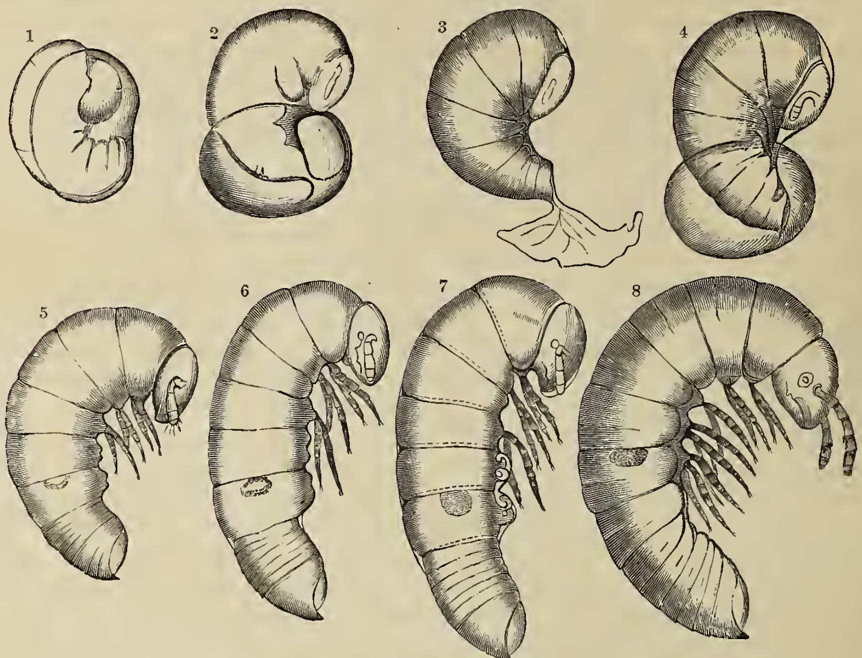
As in the Insecta, the central organ of circulation, the so-called heart, is a dorsal vessel, divided into successive chambers agreeing in number with the segments of which the body is composed, and each chamber is attached to the walls of its segment by a pair of triangular muscles. The blood penetrates these chambers through a pair of lateral slits, and, according to Newport, a portion of it is again driven out through a small artery situated in front of the slit, but the greater part is driven forward and discharged into the cavity of the head through an aorta which divides into three branches. Respiration, as already stated, is effected, as in the Insecta, by the agency of tracheæ, which open by regular stigmata, usually placed either towards the middle of the ventral surface close to the articulations of the legs, or in the membrane uniting the dorsal and ventral plates of the segments. In one type, however, the stigmata form a single row of openings in the middle of the upper surface of the body, one being placed close to the hinder margin of each of the dorsal plates and in *Peripatus* the tracheæ are short and open irregularly in all parts of the skin of the animal.

The reproduction of the Myriopoda is always by eggs, and the young animals, on quitting the egg, although allowing the general characters of their parents to be recognised, present certain rather important differences from them. Thus the numbers of the body-segments, of the joints in the antennæ and of the ocelli are always less, and the young Myriopod, when first hatched, has only three pairs of legs attached to the three segments immediately behind the head. With each change of skin undergone by the larva the number of each of these parts increases until the adult construction is attained; new segments are formed in the body between those already in existence, new joints are added to the antennæ in the same way, new ocelli make their appearance on the sides of the head, and the number of leg-bearing segments steadily increases.

In their habits the Myriopoda are generally darkling creatures, living a concealed life in the ground, under stones, in crevices of rocks and buildings, and under the loosened bark of trees. They are distributed in all parts of the world, but the largest and finest species are all inhabitants of hot climates, where some of them attain gigantic dimensions. The food of some of them is of a vegetable nature, although it would appear that even these will not disdain animal food on occasions; others confine themselves to the latter diet, and are most formidable predaceous creatures.

The oldest known members of the class, in fact almost the only ones known to occur in the fossil state, belong to the vegetarian forms above mentioned (the Chilognatha). Remains of several species apparently belonging to this order, although showing very peculiar characters, have been discovered in the Carboniferous formation of North America, some of them even contained in the hollow trunks of trees of the genus *Sigillaria*. One or two allied forms have also been detected in the Coal-measures of Britain. The Permian rocks of Germany, immediately succeeding, or, perhaps, concluding the

Carboniferous period, have also furnished a peculiar species. A species referred to *Geophilus*, and therefore to the carnivorous order Chilopoda, occurs in the lithographic slates of Solenhofen. A few Tertiary fossil species are known, and many occur enclosed in amber.



THE DEVELOPMENT OF JULUS TERRESTRIS. (*After Newport.*)
1, Embryo at rupture of egg; 2, at end of first day; 3, on third day; 4, on ninth day; 5, newly-hatched *Julus* on seventeenth day; 6, on nineteenth day; 7, on twentieth day; 8, on twenty-sixth day.

We divide the Myriopoda, including the abnormal type *Peripatus*, into four orders, as follows :—

* *Breathing Apertures regular Stigmata.*

1. Chilopoda (Centipedes), with the antennæ simple, the body depressed, the dorsal and ventral plates horny, united by a membrane; the legs inserted in single pairs at the sides of the segments, with the exception of the first two pairs, which are converted into mouth organs.

2. Chilognatha (Millepedes), with the antennæ simple, the body usually convex, or even cylindrical, the dorsal plates bent round so as to meet the narrow ventral plates nearly in the middle line of the body, each segment, after the fifth or sixth, with two pairs of legs.

3. Pauropoda, with branched antennæ.

† *Breathing Apertures scattered.*

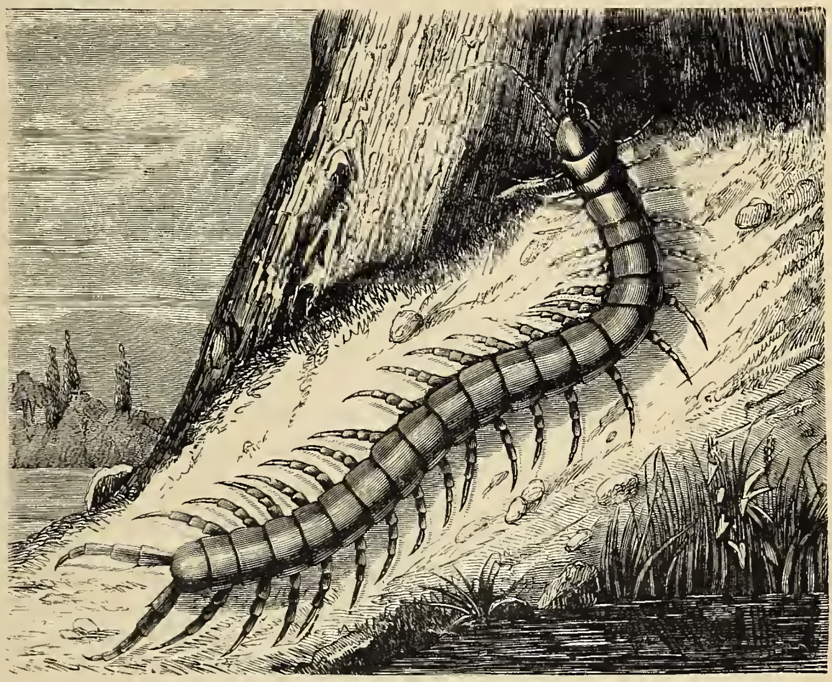
4. Onychophora, worm-like, with a soft skin, simple antennæ, and legs terminated by two claws.

ORDER I.—CHILOPODA.

The leading characteristic of the Myriopods of this order has been already indicated (p. 150). It consists in the conversion of the first two pairs of legs into auxiliary organs of the mouth. In general the dorsal part of the first two segments is reduced to a rudimentary condition, and their limbs are always curiously modified. Behind the lower lip, of which the middle part is formed by the united halves of the labium, while the lateral portions consist of the maxillæ, the whole united into a single plate, the limbs of the first body-segment make their appearance, the coxal portions being united in the middle line so as to represent a sort of second labium, from which springs a pair of three-jointed organs like palpi (the homologues of the first pair of legs). These parts are feebly developed, but the limbs of the second segment attain a large size and a very remarkable structure. Their basal parts are expanded into two broad, irregularly triangular plates, united in the middle, each of which bears a sickle-shaped organ composed of four joints, representing the true limb. The basal joint of these hook-like parts is of large size, and is followed by two broad but very short joints, and these again by a long, powerful,

curved, tapering joint, terminated by a sharp, perforated claw, through which the poison secreted by a gland can be poured into the wounds inflicted by the point. The whole of this apparatus lies flat upon the under surface of the head, usually closing the mouth from beneath entirely.

The segments behind the head, which vary in number between sixteen and over a hundred, are formed by separate horny dorsal and ventral plates, joined at the sides by a membranous part in which the stigmata are usually situated. Each of these plates more or less overlies the one behind it, and in some forms the alternate dorsal plates are so large as to cover those between them, causing the number of segments to appear only half what it really is. In these cases, however, the ventral plates indicate the true number of segments. The rudimentary condition of the dorsal plates of the first or first and second segments has already been mentioned; and these, and the third segment, are to be regarded as constituting a thoracic region homologous with that of insects. Each segment of the body, from the third onwards, bears a pair of jointed legs, which spring from the borders of the ventral plates and stand out from the sides of the body. They are usually of moderate length, but sometimes very long. The legs attached to the last segment are generally much longer and stronger than the rest, and differ from them also in being directed backwards nearly in a line with the body. The antennæ are long, composed of many joints, and tapering in form. The stigmata are usually placed on the alternate segments, and lead into a system of tracheæ closely resembling the type seen in insects. The organs of reproduction open at the posterior extremity of the body, and the impregnation of the females is said to be effected by the agency of spermatophores, which the males attach to irregular webs which they spin close to the ground.

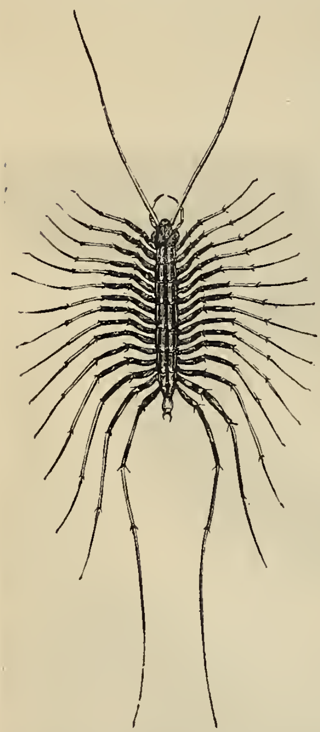


SCOLOPENDRA CINGULATA.

The Chilopods are spread over all parts of the earth, but the species of temperate countries are mere pygmies when compared with some inhabitants of the tropics. They are all shunners of light, retiring during the day to hiding-places in the ground, under stones and the bark of trees, and in the crevices of rocks, buildings, &c., and coming forth at night in search of their food, which consists of insects, worms, and other small animals. When disturbed, most of them run with considerable rapidity, and with an undulating, more or less snake-like, movement of the body; and if seized or otherwise interfered with they have no scruples about making use of the formidable nippers formed by the second pair of limbs. The poisonous secretion which, as already stated, is poured forth through the perforated point of these organs, renders the bite of the larger species very formidable; but even the small British species, such as *Lithobius forficatus*, will attempt to bite the fingers of their captor in a most savage manner. The order may be divided into two families, the first of which includes only a comparatively small number of curious forms, while the second comprises the great majority of the species, which vary considerably in character.

FAMILY I.—SCUTIGERIDÆ.

The Myriopods forming this family are remarkable for the great length of their limbs and antennæ, the latter, and frequently some of the former, being longer than the body of the animal. They are further distinguished by the possession of a pair of regular compound eyes, by the great length of the jointed part of the first pair of limbs, which project like palpi from the sides of the head, and by the small number of body-segments. These would appear to be fourteen besides the thoracic segments, but the dorsal plates are enlarged so that the alternate ones cover those lying immediately behind them, and thus the body shows eight dorsal and fifteen ventral plates. The dorsal plates are rounded behind and deeply notched in the middle, and in each notch a stigma is situated. The legs correspond in number to the ventral plates, and are long and slender, increasing in length towards the posterior end of the body. The tarsi are very long, whip-like, of two parts, and finely annulated.



SCUTIGERA FORCEPS FROM NORTH AMERICA. (*Nat Size.*)

These curious creatures, although by no means numerous, are spread over the greater part of the earth's surface, but abound more especially in warm countries. They are exceedingly active, and run freely up perpendicular surfaces. The largest known species is the *Scutigera nobilis* from India and the Mauritius, which measures two inches in length; the best known European species is *Scutigera coleoptrata*, which inhabits the south of Europe and north of Africa, and is about four-fifths of an inch long.

FAMILY II.—SCOLOPENDRIDÆ, OR CENTIPEDES.

The members of this family are more elongated and have a greater number of body-segments than those of the preceding group; the antennæ are shorter than the body; the organs of vision, when present, consist of groups of ocelli placed on the sides of the head; the jointed appendages of the first thoracic ring do not protrude, and have a small claw at their extremity; the legs are of moderate length and inserted close to the ventral plates, which reach the sides of the body; and the stigmata are placed in alternate segments, in the membranous portion which unites the dorsal and ventral plates. The tarsi consist of one or two joints, which are not annulated.

These creatures, the best known of which are called Centipedes, or Galley Worms, are distributed nearly all over the world, and everywhere they display the same general habits, being ferocious animals of prey, lurking in dark places and in the ground, and using their formidable footjaws for the destruction of their prey and their defence against enemies. The tropical species are gigantic in comparison with the European ones, which are not numerous. The best known European species belong to a genus (*Lithobius*), which is the type of a peculiar sub-family LITHOBIIDES, characterised by having numerous ocelli on the sides of the head, and the second thoracic segment represented by a dorsal plate. Thus there are sixteen segments with dorsal plates behind the head, and fifteen of these are provided with ambulatory legs. Several species occur in Britain, and of these the commonest (*Lithobius forficatus*) is found all over Europe. It is usually about an inch long and of a shining reddish-brown colour, with the head and antennæ redder and the legs yellowish, and it occurs almost everywhere in the ground, under stones and the bark of trees, and in cellars and dark outhouses.

In the true SCOLOPENDRIDES, a few of the smaller species of which occur in Europe, while the majority and all the largest forms are inhabitants of tropical and sub-tropical regions, the ocelli are never more than four in number, but the segments of the body are more numerous than in *Lithobius*, being always over twenty. One of the largest European species (*Scolopendra cingulata*, p. 153) is three inches and a half long, and is found in the south of Europe, and especially in France. It is of a rusty yellow, with the head and antennæ and a central band and the margins of the segments green. In India and South America several species attain a length of nine or ten inches, and we have seen

specimens from the forests of the equatorial part of the latter region over a foot in length. According to Ulloa, Centipedes were to be seen in Carthagena in his day three feet long and four or five inches broad.

The GEOPHILIDES, which are entirely destitute of ocelli, differ further from the preceding in having the body extremely long and slender, composed of from fifty to over one hundred segments. The tarsi are of a single joint. Some of the exotic species of this group attain a great length and an enormous number of segments. Thus *Geophilus Cumingii*, from the Philippines, is five inches long, and contains 160 segments, and *G. Gabrielis*, from the Canaries, grows to a length of over seven inches, and shows 163 pairs of legs. A good many *Geophili* inhabit Europe, and we have several in Britain, such as *Geophilus longicornis*, which grows to a length of three inches, and has fifty-five pairs of legs, and *G. subterraneus*, a species half an inch longer and with a considerably larger number of segments (seventy-eight to eighty-three). Both these species are common, and may frequently be turned up in garden ground, where they live upon the larvæ of insects and other soft-bodied creatures met with in such situations. *Geophilus longicornis* is luminous in the dark, and another British species has received the name of *Geophilus electricus*, on account of its manifesting the same property very strikingly.

ORDER II.—CHILOGNATHA.

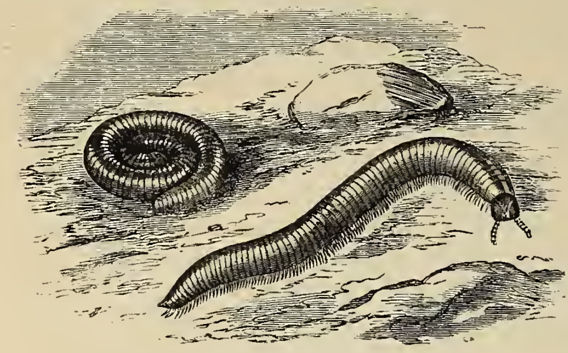
In this second order of Myriopoda the head is usually large and placed perpendicularly, and all the three so-called thoracic segments have the dorsal part freely developed; nor are the limbs of the first two segments converted into organs connected with the mouth. The number of body-segments varies between nine and eighty or more, and the form of the segments is also very variable, but each apparent segment beyond the fourth or fifth is furnished with two pairs of legs, and with two pairs of regular stigmata placed near the origin of these limbs. The limbs are sometimes deficient on the first thoracic segment. In internal structure the Chilognatha present some peculiarities. The main tracheæ do not unite after the insect type, but form branching tufts, the fine ramifications of which run to the neighbouring organs; and the organs of reproduction in the great majority do not open at the posterior of the body, but in the coxæ of the second or third pair of legs. The males are provided with peculiar copulatory organs in the sixth or seventh segment, which in this case wants one or both pairs of legs. The eggs are deposited in a mass in a cavity of the earth. The form of the newly-hatched young, and its progress towards the adult condition, have already been indicated (see figures on p. 152). The presence of two pairs of limbs upon each ring of the body would seem to show that these may be really equivalent to two segments united. We may recognise the following four families :—

FAMILY I.—JULIDÆ, OR MILLEPEDES.

The Julidæ, commonly known as Millepedes, from the great number of their legs, sometimes called Galley Worms, a name which more properly belongs to the Scolopendridæ, and sometimes, erroneously, Wire Worms, have usually a long cylindrical body, composed of segments which form a complete horny ring, the dorsal plate surrounding the whole body, with the exception of a very small sternal piece firmly united to it by sutures, and in which are situated the insertions of the legs and the small stigmata. The bases of the legs are thus brought close together and to the middle line of the body. The head is large, with short antennæ, and aggregated ocelli, which, however, are sometimes entirely wanting; and the mouth is formed for biting.

These animals are distributed in all parts of the world, the largest species occurring in the tropics. They are nocturnal, and live in or on the ground, and under stones and the bark of trees. They move slowly, creeping along by means of their short and slender legs, the motion of which presents a curious spectacle. Their food consists of both animal and vegetable matters; they also attack fleshy, growing roots, a propensity that often causes them to be mischievous. The species are numerous, and most of them have the power of emitting an acrid fluid of disagreeable odour from small apertures pierced in the dorsal part of the segments, which have been mistaken for stigmata by some observers. One of the best known species is the *Julus sabulosus*, a dark greyish-brown or blackish creature, about one inch and a half long, with the borders of the segments lighter, and two reddish lines down the back; and another, perhaps equally abundant, is the *Julus terrestris*, which is similar, but rather smaller, and destitute of the two reddish dorsal

lines. Both these species are common in Britain and most parts of Europe. Some British and European species are considerably larger than these, but the giants of the family are to be sought within the tropics, species of the genera *Spirostreptus* and *Spirobolus* inhabiting India, Africa, tropical America, and the West Indies, attaining a length of from six to nine or ten inches. All the species have the power of rolling themselves up into a spiral form with the legs concealed.



JULUS TERRESTRIS.

FAMILY II.—POLYDESMIDÆ.

These animals are very nearly related to the preceding, but although the dorsal plate is continued on to the ventral surface, it is generally furnished with a dilatation at the sides, and the insertions of the limbs are separated by a distinct sternal piece. In general habits they resemble the Julidæ, and are chiefly found under bark, where they are often abundant. They generally have no eyes, and the number of segments is twenty; they are also more or less depressed, and thus present a general resemblance to the Scolopendridæ.

FAMILY III.—SIPHONIZANTIA.

This is another family allied to the Julidæ, but differing from it in more important characters than the preceding. The body is semi-cylindrical, and the dorsal plates of the segments encroach only a little upon the under surface. The head is small, and concealed beneath the margin of the first segment; and the clypeus in combination with the organs of the mouth, which are united, forms a sort of conical sucking organ. The legs are short, and do not project beyond the sides of the body. The species, which are few in number, are of comparatively small size, but consist of numerous very short segments. They are found in rotten stumps of trees. One species (*Polyzonium germanicum*), about half an inch long, is found on the continent of Europe, especially in Germany and Poland. The rest are for the most part exotic.

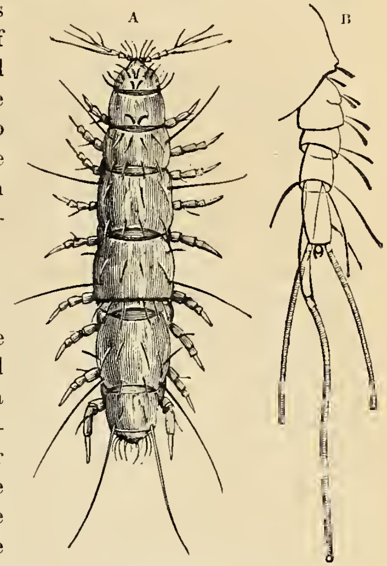
FAMILY IV.—GLOMERIDÆ.

The Glomeridæ are short ovate forms much resembling the common Wood Lice, with some of which they also agree in their power of rolling themselves into a ball. They are convex above, and composed of twelve or thirteen segments, of which the dorsal plates extend only to the margins, within which, on the lower surface, there are pleural plates separating the dorsal plates from the points of insertion of the legs. The number of pairs of legs varies between seventeen and twenty-one. Several species inhabit Europe, and most of the exotic forms belong to the Eastern Hemisphere. They may be compared to abbreviated Julidæ, and are like them in their habits.

ORDER III.—PAUROPODA.

This order has been established for one or two curious little creatures discovered by Sir John Lubbock during his investigations on the Thysanura, to which, apart from the presence of limbs on all the segments, they present a considerable analogical resemblance. These little animals consist of eight segments besides the head, and these segments bear a good many short and a few long bristles. The head also is sprinkled with hairs. The first segment of the body has a single pair of legs, while each of the following segments to the fifth bear two pairs, and may consequently be regarded as double; in fact, the divisions are recognisable beneath, and Sir John Lubbock, reckoning the head to be composed of two segments, assigns fourteen primitive segments to the whole body. The most remarkable character, however, is to be found in the antennæ, which are five-jointed and branched, with one branch terminated by a long, minutely-jointed lash; while the other has two shorter ones, between the bases of which is placed a peculiar appendage, sometimes supported on a footstalk. Such a structure of the antennæ reminds one rather of the Crustacea than of any air-breathing Arthropod.

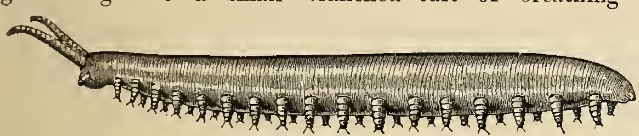
Another peculiarity of these animals is that they appear to possess no respiratory organs. There are no stigmata, and although the skin is very transparent, Sir John Lubbock could detect no tracheæ in the interior of the body. The commonest British species (*Pauropus Huxleyi*), which attains a length of one-twentieth of an inch, is an active little white creature, which may be found throughout the year among dead leaves and decaying vegetable matter in general. Two oval spots on the head are supposed to represent eyes. It appears to breed in the early autumn, and the newly-hatched young have only three pairs of legs. Sir John Lubbock describes a second but rarer British species (*P. pedunculatus*), and others have been obtained in North America.



PAUROPUS HUXLEYI.
A, enlarged 40 times ; B, antenna, enlarged 250 times.

ORDER IV.—ONYCHOPHORA.

Many years ago the Rev. Lansdowne Guilding discovered in the island of St. Vincent a curious worm-like creature frequenting dead wood and the stumps of trees, which he regarded as probably a worm, and described (in 1825) under the name of *Peripatus iuliformis.* Its true position has been frequently discussed, and for a long time it seemed to hover between the Annelids and the Myriopods, until the investigations of Professor Moseley, during the voyage of the *Challenger*, caused the scale finally to descend on the Myriopod side. These creatures are convex and worm-like, with their segmentation not particularly distinct, and the integuments of all parts of the body soft. On each side of the body are a number of short legs, terminated by a rudimentary jointed part, and a pair of hooked claws. The head bears a pair of simple, annulated antennæ, and a pair of simple eyes; the mouth, which is below, has tumid lips, and within these two pairs of horny jaws. Respiration is effected by means of tracheæ, which, however, are not connected into a regular system, but each respiratory aperture, of which a great number are scattered over the skin of the animal, gives origin to a small branched tuft of breathing tubes. As Professor Moseley says, we have here probably the first stage in the evolution of tracheæ, which would indicate that the "air-tubes were developed in the first tracheate animal out of skin glands scattered all over the body." Of the internal structure of *Peripatus* we need only say that it differs from that of normal Myriopoda in the wide separation of the ventral nervous cords, and that it has greatly developed glands, called by Professor Moseley "slime glands," probably homologous with the salivary glands of other Myriopods, which secrete in abundance a clear viscid fluid. This is ejected by the animal from a pair of papillæ placed at the sides of the mouth, in fine, thread-like jets, which combine to form a sort of network in front of the animal. It would appear that the emission of this slime is partly for defensive and partly for offensive purposes, as it takes place when the creature is irritated or handled, and is also employed, according to some observers, in the capture of insects for food. The *Peripati* are viviparous. They reside principally in rotten wood, are nocturnal in their activity, and walk in the manner of caterpillars, with the body much extended. According to Professor Moseley's observations on the Cape species (*Peripatus capensis*), the food consists of vegetable matters; but according to Professor Hutton the New Zealand one (*P. novæ-Zealandiæ*) feeds partly upon insects. The *Peripati* must be regarded as representing a very early stage in the evolution of the Arthropods from the Vermes, and hence their form is probably of great antiquity. Their peculiar geographical distribution would also point in the same direction, seeing that species of the genus are found in Central America and the West Indies, in Chili, New Zealand and Australia, and at the Cape of Good Hope.



PERIPATUS CAPENSIS. (*Nat. Size.*)

W. S. DALLAS.

CLASS ARACHNIDA.

CHAPTER I.

SCORPIONS AND SPIDERS.

ARACHNIDA—General Characters—Internal Structure—Habits—Distribution—Fossil Forms—Classification—Order ARTHROGASTRA—Lung-sacs—Classification—Family SCORPIONIDÆ—Scorpions—Family PHRYNIDÆ—Family CHELIFERIDÆ—False Scorpions—Family PHALANGIIDÆ—Harvest-men—Family SOLPUGIDÆ—Galeodes—Order ARANEIDA—True Spiders—General Characters—Internal Structure—Spinning Apparatus—Habits—Classification—TETRAPNEUMONES—Family MYGALIDÆ—Bird Spiders—*Mygale*—Trap-door Spiders—DIPNEUMONES—Family SALTICIDÆ—Saltigradæ—Family LYCOSIDÆ—Citigradæ—Tarantula—Family THOMISIDÆ—Laterigradæ—Crab Spiders—Family THERIDIIDÆ—Inæquitelæ—Malmignatte—Family TEGENARIIDÆ—Tubitelæ—House Spider—Water Spider—Family EPEIRIDÆ—Orbitelæ—Garden Spider.

IN both the preceding classes of air-breathing Arthropods, the head is furnished with a pair of jointed organs recognisable as antennæ; in the Arachnida we find no antennæ of the same kind, but the corresponding parts, when present, are converted into a pair of more or less jaw-like organs. Except in two groups the head is always intimately united with the thorax to form a single mass, called the cephalothorax, which bears in front all the organs pertaining to the head, and on its lower surface the thoracic limbs; in many cases even the distinction between thorax and abdomen is effaced. There are no wings. The organs of respiration, when present, consist either of tracheæ, or of peculiar sac-like modifications of tracheæ, to which the name of lungs or pulmonary sacs has been given. The abdomen is always destitute of limbs. The range of organisation is so great in the Arachnida that it is somewhat difficult to give any general description of the class, and we shall therefore only indicate briefly what is necessary to make the following descriptions of the orders and families intelligible.

The cephalothorax is usually covered above by a single plate, upon the anterior part of which the eyes, when present, can be seen. These are always ocelli or simple eyes, and they vary in number between two and twelve. The organs representing the antennæ are articulated to the front of the cephalothorax above the opening of the mouth, and receive their nerves from the supraœsophageal ganglion; they usually take the form of jaws, often of formidable dimensions, and in function replace the true mandibles, which are absent. They are commonly called *falces.* Of the two pairs of organs representing the maxillæ and labium of insects, the former (*maxillæ*) retain their position as organs of the mouth, their basal parts closing the mouth behind either as separate pieces, or united into a single plate, while their jointed palpi project, and frequently acquire the form and size of an additional pair of limbs. Of regular limbs the Arachnida have four pairs, of which the first may be considered to represent the labial palpi, and the others the three pairs of legs of the Insecta. The bases (*coxæ*) of all these limbs surround the sternum, but possess apparently little power of motion. The limbs springing from these coxæ consist, in the higher Arachnida, usually of seven joints., namely, a *trochanter,* which is sometimes elongated, but generally very short, a stout femur, a *tibia* composed of two unequal joints, and a *tarsus,* also consisting generally of two joints, which are sometimes annulated, and the last of which bears the claws and often other subordinate organs. In the lower types of the class of course the limbs are frequently simpler in construction, and occasionally they are represented only by rudimentary parts.

The abdomen is attached to the cephalothorax sometimes by a slender peduncle, sometimes by its whole width; and in certain of the lower forms of the class the whole animal shows no traces of divisions. In some instances also the abdomen itself is clearly divided into a larger or smaller number of segments, whilst in others no trace of segmentation is apparent. The skin covering the body of the Arachnida is generally soft and leathery, with the exception of the limbs, the joints of which are more or less horny tubes. In other cases the whole surface is horny. The skin is changed repeatedly and throughout the life of the animal, there being no fixed period for the final moult, as in the insects; thus the Arachnida, after having reached the reproductive stage, may continue to live and increase in size, and produce successive broods of young.

The mouth in the Arachnida leads into a narrow œsophagus, which in some forms (Scorpions) passes directly into the stomach, while in the majority it is clearly separated from the latter. The stomach itself presents the remarkable peculiarity that in most cases it gives origin on both sides to several cæca, often of the same number as the limbs, and which in many cases actually penetrate

more or less into them. The length of the intestine generally corresponds with that of the abdomen, at the extremity of which it opens. The amount of convolution is not great Before its termination it generally enlarges into a rather large cloaca, immediately above which the Malpighian vessels open into the intestine. The so-called fatty body of the Insecta does not occur in this class, but the body-cavity is filled with the lobes of a greatly-developed liver, in which the other internal organs are imbedded; the numerous gall-ducts proceeding from this liver unite to form eight or ten main ducts, which open into the sides of the intestine at some distance behind the stomach. Salivary glands discharging into the cavity of the mouth are also generally present.

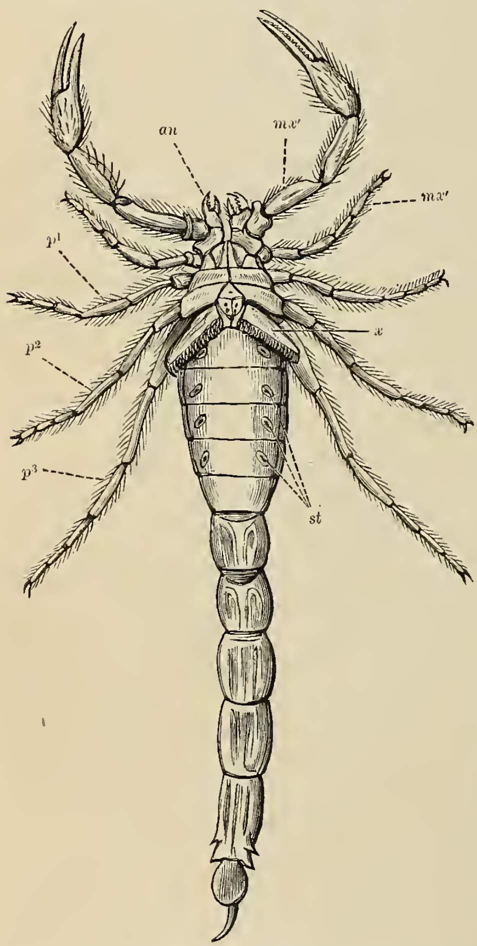
The organs of circulation and respiration show very great differences in the class Arachnida. The lowest types have no special organs of the kind. Others possess a dorsal vessel of very simple construction; while the higher forms, such as the Spiders and Scorpions, have a regular chambered dorsal vessel or heart, into which the blood penetrates through valvular apertures, while part of it issues again through small arteries given off by the chambers, and the rest through an aorta, which divides into numerous branches, distributed through the body. In the lower forms again respiration is performed by the agency of tracheæ like those of insects and Myriopods; in the more highly-organised groups, while simple tracheæ are still frequently present, the chief respiratory organs are peculiar lung-sacs, of which the ventral surface has from one to four pairs, and which show in their interior several delicate membranous folds. The nervous system exhibits almost an equal amount of variation, but in its highest development it shows an œsophageal ring with a large ganglion above the œsophagus, from which nerves are supplied to the eyes and falces, and another below the œsophagus, often united with the great ganglionic mass of the cephalothorax, and from these combined nerves issue to the organs of the mouth proper and the four pairs of legs. When the abdomen shows distinct segments, it also contains a ventral chain of ganglia united by commissures. Except in one small and lowly group, the Arachnida are all of separate sexes, and with but few exceptions they are oviparous. Many of them undergo more or less change of character in advancing towards maturity, and in some parasitic forms we find examples of retrograde metamorphosis.

In their habits the Arachnida are nearly all carnivorous, and, indeed, predaceous, living principally upon various insects and other weaker Arthropods, of which they usually content themselves with sucking out the juices, sometimes, however, devouring part of the solid substance. Among the lower forms, some feed upon solid materials of animal origin, and others upon vegetable matters, whilst some are parasitic, not only upon other Arthropods, but even upon vertebrate animals. They are mostly terrestrial creatures, but one whole order consists of inhabitants of the sea, and a few members of other groups are also aquatic in their habits. Their distribution is world-wide, but, as in most other groups, tropical countries possess the greatest number of species, and present us with the largest and most remarkable forms. Geologically, the class is of great antiquity. Unmistakable Arachnida, of forms which stand high in our classifications, occur in the Coal-measures of various parts of the world. Scorpions and true Spiders are recorded from these deposits both in Europe and in America, which also contain other forms, the precise location of which is more difficult. Fossil Arachnida also occur, although sparingly, in later deposits containing insect remains, such as the lithographic slates of Solenhofen and the various Tertiary insect-beds, and, as might be expected, Spiders are by no means uncommon inclusions in amber.

The vast range of characters presented by the multifarious members of this class, the highest and lowest of which, but for the existence of the intermediate forms, would hardly be referred to the same group, renders the classification of the Arachnida rather complex, and has given rise to considerable diversity in the systems adopted by different authors. Formerly the class was divided into two principal groups, Pulmonata and Tracheata, according as the animals breathed by lung-sacs or by tracheæ, but this mode of division has been held to be unsatisfactory on account of the analogy between the so-called lungs and the tracheæ, and the further fact that lungs and tracheæ co-exist in many forms. The actual difference in the arrangement of the groups by the abolition of this mode of division is so insignificant that it is really of little consequence whether we retain it or not, and as the mode of arrangement in accordance with the general characters presented by the various groups is perhaps more easily intelligible, we may adopt it in the present work. The following table will show the orders into which we propose to divide the class.

I.—Abdomen composed of distinct segments	Order 1.—ARTHROGASTRA.
II.—Abdomen with no distinct segments or rudimentary:—	
A. Abdomen distinctly separated from the cephalothorax, pedunculate . .	,, 2.—ARANEIDA.
B. Abdomen not separated from the cephalothorax:—	
* Furnished with tracheæ	,, 3.—ACARINA.
† With no distinct organs of respiration:—	
a. Body indistinctly ringed; four pairs of stumpy legs	,, 4.—TARDIGRADA.
b. Body worm-like; internal parasites	,, 5.—LINGUATULINA.
c. Cephalothorax of four segments; legs long; abdomen rudimentary .	,, 6.—PANTOPODA.

The first of these orders includes the Scorpions, and some other Pulmonate forms, together with the long-legged Harvest-men, the Book Scorpions, and some others which breathe by tracheæ; the second is formed by the true Spiders, in which we find lung-sacs as well as tracheæ; the Acarina include the numerous species of Mites, in which tracheæ are the sole organs of respiration; the Tardigrada are the minute creatures known to microscopists as Bear animalcules; the Linguatulina, when adult, are worm-like creatures, with a couple of hooks as the sole representatives of limbs, but in the young state show arachnidan characters; and the last order consists of some marine creatures, which may be called Sea Spiders, and which have been bandied about between the Crustacea and the present class.



UNDER SURFACE OF SCORPIO OCCITANUS.
an, falces, representing antennæ; *mx'*, first pair; *mx''*, second pair of palpi; p^1, p^2, p^3, true legs; *x*, comb; *st*, stigmata.

ORDER I.—ARTHROGASTRA.

This order includes several distinct types, of which, indeed, separate orders have been made by many zoologists, and it is not without some hesitation that we have accepted it in its present signification. The sole important character by which all its members are held together, is the possession of a distinctly segmented abdomen, which is attached to the hinder part of the cephalothorax by its whole width; in other respects we find a great variety both in external structure and in internal anatomy.

In respect of the respiratory organs especially, we find two perfectly distinct types, some forms belonging to the group breathing exclusively by lung-sacs, while the rest are as exclusively tracheal in their respiration. These lung-sacs, which occur in the highest types of this order, and associated with tracheæ throughout the next, are regarded by anatomists as modifications of tracheary organs. They are situated in pairs in one or more segments of the abdomen, and each of them communicates with the external air by a more or less slit-like opening, or stigma, pierced in the ventral plate of the segment. This aperture leads into a small, usually flattened, sac, the walls of which are folded so as to form a number of delicate lamellæ (from 20 to 100, in different cases)· dividing the cavity into so many narrow compartments, all opening into a common chamber which communicates with the outer air through the stigma. As Professor Huxley remarks, "the organ, in fact, somewhat resembles a *porte-monnaie* with many pockets." The blood circulates through these delicate membranous folds, and is thus exposed to the influence of the air, which has free access to the cavity of the sac; it is then conveyed by sinuses to the pericardial cavity, to pass thence into the heart. According to Professor Huxley the expiration of the air is effected by the agency of peculiar muscles which act on

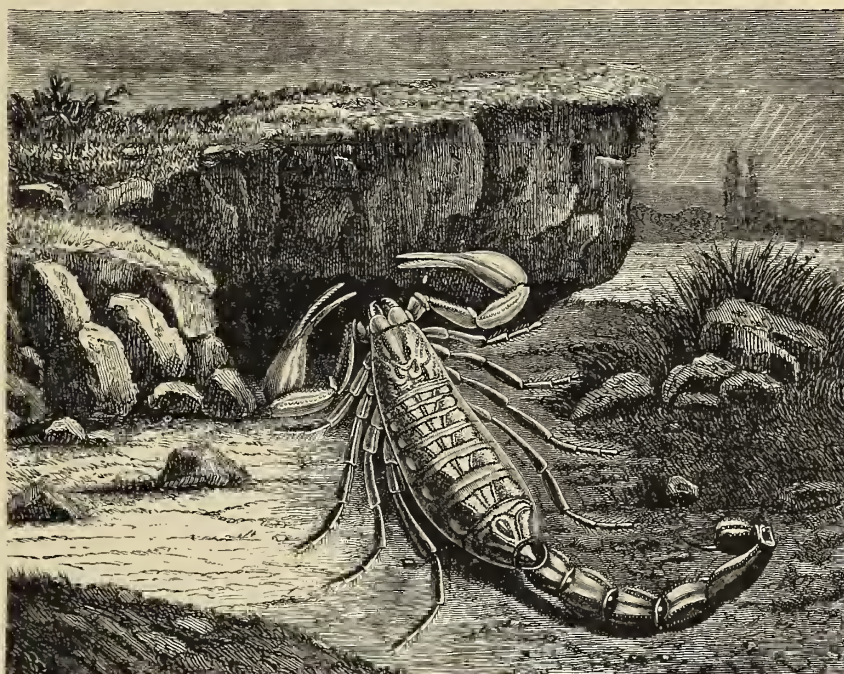
the membranous lung-sacs; some zoologists also believe that inspiration is caused by a similar agency. The true tracheæ, when present, are analogous to those of the Insects and Myriopods, open like them by stigmata, and ramify throughout the body.

The great diversity of organisation presented by the members of this order renders their division into families exceedingly clear and distinct, and we may recognise with facility the following five groups :—

I.—Respiration by lung-sacs (*Pedipalpi*).	
a. Maxillary palpi with nippers; stigmata four pairs; terminal segments of abdomen forming a slender tail, with a sting at the end	Family 1. SCORPIONIDÆ.
b. Maxillary palpi with imperfect nippers, or simple; two pairs of stigmata; no caudal sting	„ 2.—PHRYNIDÆ.
II.—Respiration by tracheæ (*Adelarthrosomata*).	
a. Cephalothorax not segmented :	
* Maxillary palpi with nippers	„ 3.—CHELIFERIDÆ.
† Maxillary palpi simple	„ 4.—PHALANGIIDÆ.
b. Cephalothorax divided into four segments	„ 5.—SOLPUGIDÆ.

FAMILY I.—SCORPIONIDÆ.

The species of this family are exceedingly uniform in their structure. They consist of a rather broad anterior part, composed of the cephalothorax and seven distinct segments following it, at the hinder extremity of which come five narrower segments forming a sort of tail, terminated by a bulbous piece having a short but sharp point. At the front we see a pair of jointed organs having regular nippers, like the so-called claws of a Crab or Lobster, and behind these four pairs of ambulatory limbs. The type is so interesting and important, however, that we must describe its structure a little more particularly.



ANDROCTONUS (OR SCORPIO) OCCITANUS.

The upper surface of the cephalothorax is covered by a shield-like horny plate, upon which from three to six pairs of simple eyes are to be seen, a pair of extra size being placed close to the middle line of the shield, while the rest are arranged variously towards the margin, according to the genera and species. The seven plates which follow this cephalothoracic plate on the back of the animal represent so many abdominal* segments, but are connected with the corresponding sternal plates only by soft skin, with the exception of the seventh, which joins its sternal plate at the hinder part. The other six dorsal plates have only four distinct sternal plates to correspond with them, and

* Prof. Huxley speaks of them as thoracic.

these appear to represent the third, fourth, fifth, and sixth; each of them presents a pair of stigmata leading into lung-sacs. The five segments following these, which form the wider part of the body, consist of complete horny rings, or rather short tubes, articulated in such a manner as to give the tail, which they form, considerable freedom of movement. The last joint of this tail, regarded as the equivalent of the telson of the Crustacea, is a bulbous piece, swollen at its base, and narrowed and curved into a hook at the free end; the bulb contains a pair of glands which secrete a poisonous fluid, which is conveyed by ducts to the minutely but doubly perforated point of the hook, and renders the sting of the Scorpion so formidable an offensive weapon.

In the Scorpions, as in most Arachnida, the representatives of the antennæ, which spring from beneath the front margin of the first dorsal piece, are a pair of organs affiliated to the mouth, but in the present group, instead of forming two-jointed jaws, the chelicerae are composed of three joints, the last two of which form small pincers. A large labrum is followed by a very small mouth-aperture, on each side of which are the bases of the maxillæ, which are true foot-jaws, having a distinct masticatory surface, while their elongated palpi are the large pincer-like organs which form so striking a characteristic of the Scorpions. Of the four pairs of walking limbs which follow these chelate palpi two have their basal joints forming part of the boundary of the mouth, a circumstance which has led some anatomists to regard them as representing the maxillæ and labium, and the large palpi as belonging to the mandibles. The ambulatory limbs are provided with three claws. Behind the origin of these limbs are traces of the sternal portions of the first and second free segments, the first bearing the valves which cover the generative aperture, while the second supports a pair of very singular comb-like appendages, the function of which does not seem to be very clearly made out.

The alimentary canal, which starts from the minute aperture of the mouth, forms a simple tube continued through the whole length of the body, and opening in the segment immediately preceding the sting.

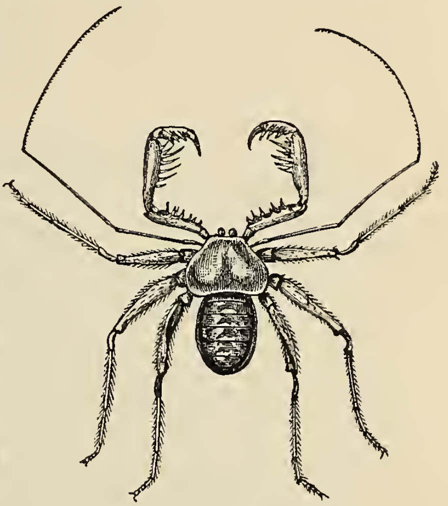
The Scorpions are the largest and most formidable members of the class Arachnida, and they are for the most part confined to the warmer regions of the earth. In Southern Europe, indeed, a few species are found, and some of these are of moderate size, such as the *Androctonus occitanus*, which occurs throughout the Mediterranean region, and measures upwards of three inches in length, but in hot countries there are Scorpions of nearly double this stature. The genus (*Androctonus*) to which the largest European Scorpion belongs, is chiefly represented in Africa, although its members also occur in Western Asia, as well as in Europe. Its name, which signifies "Man-killer," indicates the dread with which these creatures are regarded in Africa, where their sting is certainly productive of very painful consequences, although whether it is ever fatal would seem to be still a matter of some doubt. The European species, at any rate, do not appear to produce any very serious effects. *Androctonus occitanus* is said to be the least formidable species of its genus; and the other common European Scorpion (*Scorpio europæus*) is not half the size of its companion. Both these species are to be met with in the south of France, and the second extends its range northward into Germany.

The Scorpions are light-shunning animals, concealing themselves during the day in the ground under stones and in crevices in rocks and buildings. In the twilight they come forth in search of their prey, which consists principally of large insects and their larvæ, and spiders, and when thus engaged they carry the long flexible tail elevated over the back of the body, so that the sting is about as far forward as the cephalothoracic plate. The prey is seized by the pincers of the large palpi, and then pierced by the sting and speedily killed. Scorpions generally live quite alone, and select dry places for their abode. Brought together accidentally, they will usually fight, and if one is killed the other will feed upon it; the male also, being smaller than the female, is obliged to be very cautious in his approaches to the object of his affections, lest he should be treated in the same manner. The females are viviparous, that is to say, the eggs are hatched in the enlarged oviducts, and the number of young produced may reach sixty. In their earliest days the young Scorpions are carried about upon the back of their mother.

FAMILY II.—PHRYNIDÆ.

The Phrynidæ constitute a small family of Arachnida nearly related to the Scorpions, from which they nevertheless differ in some sufficiently striking particulars. The fore part of the body is also

occupied by the dorsal plate of the cephalothorax, and this has eight ocelli, of which two, as in the Scorpions, are placed close to the middle line. The falces consist of two joints, with an apical claw; the true maxillary palpi are large and stout, and terminate either in a simple claw or in an imperfect pincer, in which the movable finger is considerably shorter than the other; while the second palpi, or first pair of legs, are long and slender, and terminated by a finely annulated tarsus. The three pairs of true legs are comparatively stout. Attached to the posterior end of the cephalothorax is the abdomen, which is flat, slightly narrowed towards the base, and composed of eleven or twelve segments; it has no comb-like appendages at its base, and the hinder extremity is not narrowed into a flexible tail armed with a sting, as in the Scorpions, although in one genus (*Thelyphonus*) the last three segments are much reduced in size, forming a short tube, terminated by a long, jointed filament. The respiration is effected by lung-sacs, the stigmatic openings of which are situated near the hinder margin of the second and third ventral plates; the sacs contain numerous lamellæ (about eighty in some species).

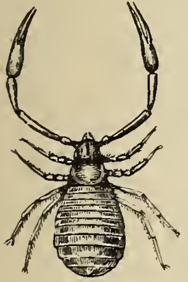


PHRYNUS RENIFORMIS.

Although destitute of the formidable sting of the Scorpion, the attacks of these creatures, which are mostly of considerable size, are dreaded by the inhabitants of the countries in which they occur. No doubt the pointed claw of the falces is perforated and connected with a poison gland, as in the true Spiders, and it is by means of these organs that painful wounds are inflicted. In their general habits the Phrynidæ much resemble the Scorpions, with which they also agree in the tubular structure of the alimentary canal. They are not numerous in species, and form only two principal genera, which, however, are represented in the tropical parts of both hemispheres, although the species are most numerous in America. They are generally from an inch to an inch and a half in length, but a species five inches long (*Thelyphonus giganteus*) has been described from Mexico. This, however, includes the annulated tail characteristic of the genus *Thelyphonus*, which is often of considerable length. In the genus *Phrynus*, in which the tail is wanting, the second pair of palpi are very long, sometimes three times the length of the body. The species of *Phrynus* are viviparous.

FAMILY III.—CHELIFERIDÆ.

This family comprises a great number of little creatures, which, in appearance, are exactly comparable to minute flattened Scorpions that have lost their tails; they are known as False Scorpions and Book Scorpions. Like the Scorpions they have the first palpi developed into long didactyle chelæ, and the second pair in the form of legs, but their basal part forms no part of the boundary of the mouth; the falces (representing the antennæ) are much reduced, and the surface of the cephalothorax, which is often divided into two parts by a transverse furrow, bears only one or only two pairs of eyes. Behind the cephalothorax follows a broad, flat abdomen, composed of eleven similar segments, and without any comb-like appendages at its base. On the first two abdominal segments are placed two pairs of stigmata, opening, however, not into lung-sacs but into regular tracheæ, which give off branches to the organs of the body in the same way as in the remaining families of the order, and in the second segment is the opening of the sexual organs, close to which are some silk glands, with the secretion from which the little creatures are said to manufacture protective coverings for themselves when they are about to change their skin, or to lie by for the winter.



CHELIFER CANCROIDES.

These little creatures, few of which exceed a sixth of an inch in length, are tolerably numerous, and inhabit most parts of the world. They are generally of different shades of brown, and have the limbs and frequently the cephalothorax paler than the rest of the body. Like the preceding groups

they lead a concealed life, making their way into any confined spaces in search of food and shelter. One of the best-known species, the so-called Book Scorpion (*Chelifer cancroides*), is very common in old houses, where it often lives in and among old dusty books and portfolios, whence its popular name. It is about an eighth of an inch long. Several allied speeies (*Chelifer muscorum*, &c.) are found chiefly in moss, while others may be met with in hot-beds and among decaying vegetable matters, upon the ground under herbage, and under the loose bark of trees. They run freely in all directions, and when alarmed hold up their little pincers in a threatening manner. Their food consists of the minute insects, mites, &c., which they meet with in the various places haunted by them; and the females are oviparous, usually producing about twenty eggs. The common house species, and probably some of the others, have the curious habit of attaching themselves by their pincers to the legs of flies, which may occasionally be found flying about thus loaded. Their object in this manœuvre does not seem to be understood.

FAMILY IV.—PHALANGIIDÆ.

The Phalangiidæ, or Harvest-men as they are often called, constitute a second family of tracheate Arachnida, and some members of this must be tolerably familiar to most of our readers. They have a short, thick body, with an unsegmented cephalothorax, to which the abdomen, usually composed of six distinct segments, is attached by the whole width of its base; the cheliceræ are three-jointed and terminated by pincers, as in the Scorpions; the first maxillary palpi are of moderate length, and terminated by a simple claw; while the second pair, and the three pairs of legs, are usually of great length and slenderness, so that the creatures walk along as if mounted upon stilts. In some exotic species, however, the legs, or some of them, are shorter and stouter, and curved or furnished with processes which add to their grotesque appearance. The tarsi consist of numerous joints, and are sometimes exceedingly long and slender The cephalothorax bears two ocelli. Respiration in these animals is effected solely by tracheæ, which open by a single pair of stigmata, each furnished with a valve, situated between the coxæ of the last pair of legs and the base of the abdomen. The Phalangiidæ are oviparous, and the reproductive aperture is situated quite at the base of the abdomen between the coxæ, and from it the female can protrude a long ovipositor.

The Phalangiidæ are numerous in species, and generally distributed over the earth's surface, although their metropolis would appear to be South America, where also they display the most remarkable forms. The species of temperate climates, and many of those of the tropics, have the legs exceedingly long and slender, and similar in their development, like the species so common in our gardens and fields. The best-known of these (*Phalangium opilio*) is rather less than a quarter of an inch long, of an ashy or yellowish grey colour, paler below. The female has a blackish band on the back, and the male an erect horn on the cheliceræ; the cephalothorax, coxæ, and femora are finely spined. This species may be found almost everywhere, but especially on walls and the trunks of trees, and although it frequently lurks in dark corners, obscurity does not seem to be so much an object with it as with many other Arachnida. Still its greatest activity is in the evening, when it wanders about in search of small insects, mites, and spiders, which it captures by a sudden rush. According to some observers, these animals take more than a year to arrive at their maturity.

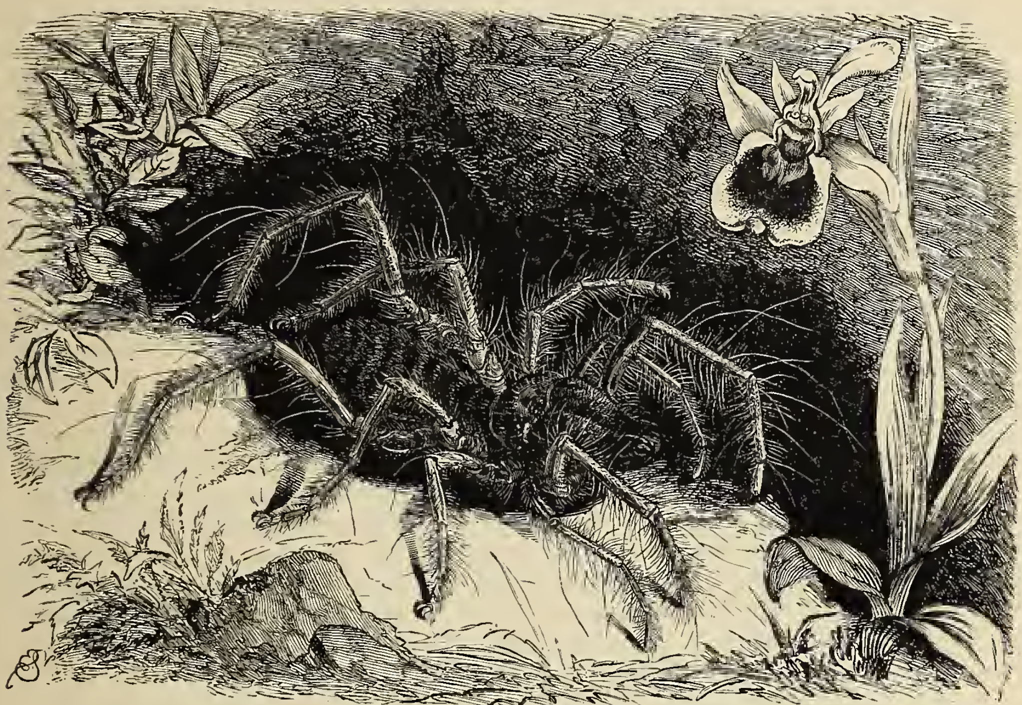
The abdomen is always of comparatively small size in these animals, but in many of the South American species of *Gonyleptes* and allied genera this part is still further reduced and almost completely concealed under the cephalothorax, which at the same time attains a somewhat increased size. This peculiarity, coupled with a remarkable development of the hind legs, renders these South American forms peculiarly grotesque. The posterior coxæ are enormously developed, so that the limbs of which they form a part seem to spring from points entirely behind the posterior end of the body, and the component parts of the legs, which are generally a good deal thicker than their fellows, are curved into various forms, and generally armed with spines and processes of different kinds.

FAMILY V.—SOLPUGIDÆ.

The Harvest Spiders of the last family are considerably more spider-like than the members of any of the three preceding ones, and in those of this fifth family we have to do with creatures which any one would denominate "Spiders," although they present, at all events, one character which

separates them not only from the Spiders proper, but from all but the last and most problematical order of the Arachnida, namely, the constitution of the cephalothorax out of four distinct rings. In point of fact, we may say that a true cephalothorax does not exist in them, but that it is represented by the head and three thoracic segments. The form, however, is exactly that of a true Spider, while the segmentation agrees rather with that of an insect, and in some respects the animals are nearly allied to the Phalangiidæ.

The head bears a pair of large ocelli, and a pair of enormous cheliceræ, greatly inflated towards the base, and terminating in pincers. Both pairs of palpi attain the length and form of legs, so that the animals appear to have five legs on each side, but the apical joints of the palpi have no claws. Behind the head come three distinct thoracic rings, narrower than the head-ring, and each of them



GALEODES ARANEOIDES.

bears a pair of true legs, the coxæ of which stand out freely from the sternum, and the apices of their tarsi have each a pair of claws. Behind the thoracic segments follows the abdomen, which is usually of an elongate ovate or pear shape, and composed of ten segments. The surface of the body is more or less hairy, and all the limbs are especially so. The respiration is by tracheæ.

In walking, these singular creatures use only the three pairs of true thoracic legs, the two pairs of leg-like palpi, of which the first is the larger, being carried in front of them, and no doubt acting as feelers. Their sole weapons are the extraordinarily-powerful, pincer-like cheliceræ, of which the lower finger is the movable one ; but these are such formidable organs that not only other insects, but even small vertebrate animals, fall victims to their attacks. Like the cheliceræ of the true Spiders, they are furnished with poison glands, the secretion from which flows into the wounds that they inflict.

These redoubtable Spiders, which are all of large or considerable size, are chiefly inhabitants of the warmer parts of both hemispheres, but more numerous in species in the eastern than in the western. They live principally in desert places, where they conceal themselves during the day in crevices, or under stones, or in cavities which they dig out in the ground. India and Persia, the great steppes and deserts of Central Asia and Southern Russia, as far north even as Siberia, and the

deserts of Arabia and Africa, are their principal habitations on this side of the Atlantic; on the other side they are best known in Central America and the West Indies. Some small species occur in the southern parts of Europe. Their food consists for the most part of insects, and their chief enemies are the big Centipedes and predaceous Beetles, which, like themselves, run about in search of booty at night.

The commonest and best-known species (*Galeodes araneoides*) is the one found upon the Russian and Asiatic Steppes, and which is also believed to inhabit Arabia and Egypt, and probably other neighbouring countries, although perhaps described under various names. It measures sometimes two inches in length. In its nocturnal wanderings, as already described, it carries the two pairs of palpi before it and keeps them in constant motion. If they come in contact with anything they are said to emit a phosphorescent light. Should the object touched be good to eat, the Galeodes dashes upon it at once, and its powerful nippers soon make an end of all weaker creatures. Even a Lizard, with a body half as long again as itself, was attacked by a Galeodes, seized by the nape, killed, and speedily devoured. Young Musk Rats, and even Bats, shared the same fate; a Scorpion twice its size was seized at the root of the tail and so disabled and destroyed. The successful combatant in this case, however, subsequently attacked a Scorpion in front, and was seized and at once killed with the sting. Captain Hutton, who observed an Indian species, probably *Galeodes fatalis*, confirms these results obtained with the Russian species, and adds that his Spider killed a young Sparrow, but did not eat it. The Solpugidæ also fight among themselves, when the conqueror devours his victim; but the females show considerable care for their young, which they watch assiduously until they are strong enough to take care of themselves.

Not unnaturally creatures so large and so well furnished with offensive weapons as the ordinary species of this family are regarded with considerable dread in the countries they frequent, and ancient writers even go so far as to declare that parts of India now desert were deprived of their human inhabitants by the fear of these Spiders. From reliable information it appears that their bite is really exceedingly painful, and gives rise, under certain conditions, to very serious symptoms; besides the direct inflammation of the part bitten, temporary paralysis, severe headache, and fainting fits are said to be among the consequences. Domestic animals are also very subject to their attacks, especially camels and sheep, which are either bitten in the feet as they move about, or wounded still more dangerously when they lie down to sleep. The sheep and camels in the summer have their lower surface nearly or quite naked. When they lie down, probably disturbing a Galeodes in his search for prey, he avenges himself at once by a severe bite, the consequences of which are so serious that the bitten animal may even die. These Spiders are fond of living among reeds and sedges, and in consequence of this predilection are often brought into the summer dwellings of the Calmucs and other inhabitants of the steppes, in the construction of which such articles play an important part. In this way their contact with man is greatly facilitated. Some thirty or five-and-thirty species are described, all of which are very similar in structure and habits.

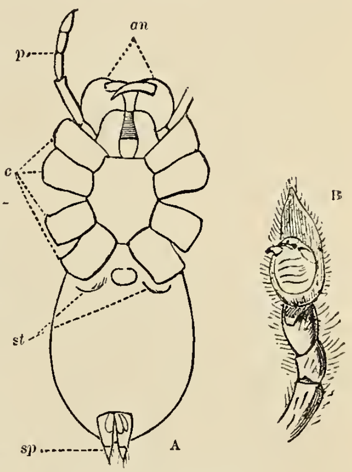
ORDER II.—ARANEIDA, OR TRUE SPIDERS.

While the members of the preceding order are for the most part strictly terrestrial in their habits, the true Spiders, to which we have now to turn our attention, exhibit a much greater variety in their mode of life. Many of them, it is true, like the Arthrogastra just described, dwell habitually on the surface of the ground, concealing themselves under stones and clods of earth, in moss and other vegetable covers, or even in burrows dug out by themselves; but perhaps an equal number disdain such grovelling habits, wander on trees, shrubs, and plants to any height above the surface, or suspend themselves freely in the air in most ingeniously constructed webs. Some even contrive to get themselves transported through the air, although they possess no wings, by a very remarkable application of the power of silk-producing, which they possess in so great a degree; whilst a few even betake themselves to the water, and construct beneath its surface comfortable little habitations of the most singular kind.

As might be expected in a group of such varied habits, the organisation of these creatures presents considerable diversity, particularly in regard to external form and details, but the main peculiarities of structure distinguishing the order are very uniformly displayed throughout. The

cephalothorax, which, in the Solpugidæ—the most Spider-like of the preceding families—is divided into four distinct rings, is here once more united into a single mass without segmentation; the abdomen, which also shows no division into segments, is attached to the back of the cephalothorax by a more or less slender peduncle; the cephalothorax has four pairs of limbs; and the antennæ are represented by a pair of falces (cheliceræ), which perform the part of mandibles, and have a movable, claw-like, terminal joint. The respiration is performed by both lung-sacs and tracheæ.

The cephalothorax in these animals is covered above by a more or less horny plate, towards the front margin of which a group of simple eyes is situated. These are generally eight in number, but sometimes only six, or even less, and their relative position is of considerable importance in the determination of species and genera. The falces, which spring from the front of the cephalothorax above the mouth, are generally bent down vertically, but sometimes project more or less forward. Each of them consists of two joints, of which the basal one is large and stout, and furrowed along the inner margin, while the second is claw-like, sharp, and articulated to the apex of the first in such a manner that it can be folded back into the groove of the latter, and when erected it forms a biting organ more or less opposed to that of the opposite side. These may, in fact, be regarded as the jaws of the Spider, and they are rendered formidable weapons by the circumstance that they are perforated, and the canals passing through them to the apex of the claw-joint receive the ducts coming from a pair of poison glands, consisting of blind sacs, which extend more or less into the cephalothorax. The fluid secreted by these glands is poured into the wounds inflicted by the claws of the falces, and its effect upon the animal attacked is very marked.



LYCOSA ANDRENIVORA.

A, under surface of female: *an*, falces or cheliceræ; *p*, maxillary palpus; *c*, coxæ; *st*, stigmata; *sp*, spinnerets. B, maxillary palpus of male, much enlarged.

As in the Arachnida generally, no mandibles are to be recognised, but the maxillæ are plainly developed, and bear a pair of palpi consisting of several joints. In the females these are simple organs like the legs, but shorter, and furnished with a claw at the end; in the males the last joint is inflated and excavated, and usually furnished with peculiar appendages which are employed in the transfer of the fertilising elements to the reproductive organs of the female. The labium, or part of it, would appear to be represented by a small piece projecting forward between the bases of the maxillæ, and which is either joined to or separate from the sternal plate occupying the lower surface of the cephalothorax, and from the edges of which the limbs take their origin, the first pair, which, as we have already seen, may be regarded as representing a second pair of palpi, as well as the rest. The legs consist of the usual number of pieces—a large coxa, a small trochanter, and a well-developed femur, followed by a tibia of two pieces, and a tarsus also usually of two joints. At the extremity of the tarsus are two claws, often associated with other organs which may be noticed under the families. The abdomen is generally covered with a soft skin, and except in a few instances shows no indications of its being originally composed of segments; near the apex on the under side it bears two or three pairs of spinnerets, to which we shall have to refer by-and-by.

In their internal anatomy the Spiders conform to the type already described (pp. 158, 159), but show certain special peculiarities. Thus the œsophagus has horny walls and terminates in a muscular dilatation, attached by a strong muscle to the back of the cephalothorax—an arrangement which renders it an efficient suctorial apparatus. The stomach is furnished on each side with five blind tubular extensions, which run towards and usually penetrate more or less into the palpi and legs; and the intestine continues tubular to near the extremity of the body, before reaching which it is dilated into a somewhat globular rectum. All these parts are kept in place by the voluminous lobes of the liver, among which the numerous branches of the Malpighian vessels are seen; these combine to form a pair of ducts which open into the dilated rectum. The organs of circulation consist of a chambered heart or dorsal vessel situated in the abdomen, and from which numerous arteries are given off, while it is continued forward as an aorta into the cephalothorax. This divides

after a time into two main branches, and sends forth a great number of arteries to the organs of the cephalothorax and the limbs. Respiration is effected, as already mentioned, partly by lung-sacs and partly by tracheæ. The former, of which there are one or two pairs, are situated in the basal part of the abdomen, where they open by slit-like stigmata protected by small special plates (*opercula*). Their structure and mode of action are the same as already described in the Scorpion. The tracheæ consist of two main stems, with more or less numerous branches, sometimes possessing more or less distinct internal fibres, sometimes partially or wholly destitute of anything of the kind. The main stems open to the air by a pair of stigmata situated in the lower surface of the abdomen, sometimes close to those of the lung-sacs, sometimes at the extremity of the body. The aperture of the generative organs is placed in both sexes at the base of the abdomen, between the stigmatic openings. The central nervous system is much more concentrated than in the Arthrogastra, consisting only of a central or supraœsophageal ganglion and a great nervous mass behind the œsophagus, the latter showing on each side four projecting portions, from which the nerves of the limbs are given off.

Besides these internal organs, the Spiders universally possess a set of glands for the production of a viscous fluid which has the property of hardening upon exposure to the air, and forms the silky threads which play so important a part in the lives of these animals. These silk-producing glands are exceedingly numerous, and pour out their secretion through a multitude of minute tubes situated on the lower surface of a set of peculiar organs known as spinnerets, placed near the extremity of the lower surface of the abdomen. There are from two to four pairs of these organs, which are sometimes quite short and nipple-like, placed close together in a little bunch, while sometimes one or two pairs are more elongated, and even divided into joints. In the latter case it is only the apical joint that bears the spinning tubes or "spinnerules" on its lower surface. The latter consist of microscopic horny tubes, through the minute apertures at the extremity of which the silky secretion escapes in threads of extreme fineness, a number of which unite before their consolidation to form the threads with which we are familiar. The production of these silky threads is, indeed, the most striking characteristic of the Araneida, and it enters more or less importantly into all their habits of life. By means of it they construct their dwellings, and some of them make most ingenious nets for the capture of prey; they make use of it continually when prowling about, as a safeguard against falling; they employ it in the construction of bridges, to cross from one elevated situation to another, and even as a means of aërial transport. The two last-named uses of the silky material require a few words of explanation here, as they are common to Spiders of several families. For the formation of a bridge from one tree, or other elevated object, to another, the Spider places itself on the summit of its resting-place with its front to the wind, and clings firmly to its support, usually with the aid of a few short threads stretched transversely to the direction in which it is looking. It then attaches a thread to the surface on which it is standing, and elevates the extremity of its abdomen as much as is possible. The wind immediately catches the short thread thus produced and exposed to its action, and draws it out continually, forming a loop of gradually increasing length, which floats away until it comes into contact with some solid body, to which it clings. The Spider has then only to draw the line tight and fasten it, and his communication with the distant point is complete. The same process is adopted with a view to an aërial excursion, a mode of diversion to which young Spiders of several families are very much addicted especially in the fine days of autumn. In this case, however, when the Spider feels that the quantity of silk that it has produced is sufficient to enable the aërial currents to bear it up into the air, it cuts away the original attachment of the thread and allows itself to be carried off.* Sometimes these flying threads are excessively numerous, and on their descent cover everything; they are particularly striking on hedges, and constitute, at all events, one of the causes of the phenomenon well known in the country as "gossamer."

The Spiders are all oviparous, and it would appear that the female, when once impregnated, produces several batches of eggs at considerable intervals of time. The number of eggs produced at once varies, but they generally form a considerable mass, enclosed by the female in a silken bag, which she sometimes carries about with her, sometimes conceals in her nest, and sometimes attaches to

* According to many writers no preliminary attachment of the thread takes place, but the Spider simply emits some fluid from the spinnerets, and allows the air to carry it away.

stones, plants, and other objects. The young resemble their parents in general form and structure, and undergo no metamorphosis.

In their habits the Spiders are all predaceous, and their prey consists almost entirely of small Arthropods, especially insects. In the capture of these they adopt various devices: some of them creeping about among plants and such objects until they find themselves within reach of a desirable booty, or lurking in dark corners to rush out upon any passing victim, others directly pursuing the fly or other insect that they have selected with a genuine cat-like stealthiness, while others weave most beautiful and ingenious snares for the capture of their prey. In all cases, however, the fate of the victim is the same; the Spider buries the claw-joints of its falces in the body of its prey, the juices and softer parts of which are then sucked out by the action of the muscular apparatus appended to the œsophagus.

Of this order several thousand species are known from all parts of the earth, but they are nearly all of small or moderate size, with the exception of a few tropical members of certain familes which attain comparatively gigantic dimensions. In general the species inhabiting warm countries have little advantage in point of size over their relatives in temperate climates. The species are, however, more common in warm regions.

Fossil Spiders are not numerous, especially in the older rocks. Nevertheless, species occur in the Lithographic Slates of Solenhofen, and, as in the case of the Scorpions, one or two have been recorded from the Coal-measures of Silesia and Bohemia. They are more numerous in the Tertiary insect-beds, and a great many have been preserved in amber.

In the classification of the great number of Spiders forming this order there is not unnaturally some little difficulty, and the consequence is that nearly every original author adopts a method of his own, the results of which, as regards the bringing together of the different forms, are often very divergent. The following division into families, which is a slight modification of Gerstäcker's arrangement, will serve, we think, to give the reader a good general idea of the mutual relations of the different types:—

I.—Two pairs of lung-sacs and two pairs of spinnerets; claws of falces bending downwards	Tribe I.—TETRAPNEUMONES.
One family	Family 1.—Mygalidæ.
II.—One pair of lung-sacs; usually six or eight spinnerets; claws of falces bending inwards	Tribe II.—DIPNEUMONES.
A. *Vagabundæ.* Ocelli usually in three rows; wanderers which spin no webs:—	
* Cephalothorax nearly rectangular	Family 2.—Salticidæ.
† Cephalothorax narrowed in front	Family 3.—Lycosidæ.
B. *Sedentariæ.* Ocelli in two rows; makers of webs for the capture of prey:—	
* Abdomen broad and depressed	Family 4.—Thomisidæ.
† Abdomen moderate, or, if broad, very convex:—	
a. Intermediate pairs of legs shorter than the others; webs more or less tubular	Family 5.—Tegenariidæ.
b. First pair of legs usually the longest; webs irregular . .	Family 6.—Theridiidæ.
c. First and second pairs of legs longer than the others; webs with more or less regular radiating and concentric lines .	Family 7.—Epeïridæ.

TRIBE I.—TETRAPNEUMONES.

FAMILY I.—MYGALIDÆ.

The group of the Tetrapneumones, or Four-lunged Spiders, which includes only the single family of the Mygalidæ, is distinguished not only by the presence of four stigmatic openings towards the base of the abdomen, but also by the possession of only four spinnerets, two of which are very small, and by having the claw of the falces bent downwards, so that those organs are kneed. This family includes a number of species, for the most part of large or considerable size, and some of them among the very largest of Spiders. They are mostly confined to the warmer parts of the world, only a few, and those comparatively small, extending their range into southern Europe, while a single species alone is recorded as an inhabitant of Britain.

The gigantic species of the typical genus *Mygale*, in which the body is covered with a rough, hairy coat, and the legs are also stout and hairy, chiefly inhabit the warmer parts of America and the West Indian Islands, although several species of them, and some of them of large size, are found in the Eastern Hemisphere. So far as the observations of naturalists at present go, most of them, at any rate, do not burrow in the ground, but reside in the grooves and fissures of the bark of trees, in the crevices between stones, and in other sheltered places, where they commonly spin a more or less tubular silken dwelling of suitable size, within which also the female deposits her eggs, enclosed in a regular case of white silk, to the number, according to some observers, of 1,800 or 2,000. The Spiders usually go in pursuit of their prey in the evening and during the darkness of the night, when they seize upon and destroy all the insects and other Arthropods that they are able to surprise and overcome, whilst, according to stories which have come down to us from a tolerably distant past, they are not content with insects alone, but even prey upon small birds and other Vertebrates. It would appear, indeed, from an observation of Mr. Bates, that there is some truth in their possession of these bird-catching propensities, in allusion to which Linnæus gave one of the large Surinam species described and figured by Madame Merian the specific name *avicularia.* Mr. Bates on one occasion found two small birds hanging in a torn web which was stretched across a cleft in a tree. One of them was already dead; the other, upon the body of which the Spider was resting, was at the point of death, and died soon after his taking it in his hands. He found that the observation of this habit of the Spider was quite new to the natives on the banks of the Amazon, and thus some doubt still remained as to its powers of bird-catching, and we believe that the gigantic Spiders which have been brought to our Zoological Gardens from South America have not been experimented upon with birds; but Mr. Bartlett has informed us that one of them attacked and killed a mouse. At the same time, it is very curious that the formidable falces of the large Mygalidæ are regarded with so little dread by the Indian children in the Amazonian region, that Mr. Bates actually found the latter on one occasion leading about one of these monsters by a thread put round his middle. The specimens that have been kept in the Regent's Park were fed chiefly upon Cockroaches and Meal Worms; one that was kept some years ago in Danzig killed and devoured some young frogs and other Amphibians. Several of the species exceed two inches and a half long, and their legs cover a surface of five or six inches in diameter.

A considerable number of species of rather smaller size than the above, and chiefly inhabiting the Old World, live in burrows which they excavate in the ground and line with a tube of silk. They generally close their habitations with a regular, closely-fitting door, attached to one side of the aperture by a silken hinge, and, from this peculiar construction of their domicile, they are known commonly as "Trap-door Spiders." The trap-door is composed of earthy particles firmly held together with layers of silk, and, although sometimes it consists of a mere flap falling down over the aperture, it is, in most cases, a regular stopper, accurately fitting into the orifice of the burrow. In some instances the Spider shows still more ingenuity in fitting up its abode as a place of refuge. After making the main nest, it works through at one side, and there digs both upwards and downwards obliquely, so as to produce a side chamber into which it can retreat should some enemy succeed in opening the trap-door; and the lateral chamber is cut off from the main burrow by a silky curtain-like door, which hangs before it, and thus apparently completes the inner lining of the tube. *Cteniza fodiens*, figured, with its nest, of the natural size, in our Plate 65, is a well-known South European species, especially abundant in Corsica. These Spiders issue from their nests at night in search of prey, and, after they have retreated into their fortresses, they will resist the opening of their trap-doors by clinging to the lining of the tube and to the inner coat of silk composing the doors. The females deposit their eggs in a silken cocoon at the bottom of their nest, and are said by some naturalists to carry their young about with them for a time after they are hatched.

Some of the species, including the single British type of the group (*Atypus Sulzeri*), construct a somewhat different kind of nest. *Atypus Sulzeri*, a Spider nearly half an inch long, with a large cephalothorax and enormous projecting falces, is found in several parts of England, principally in the south, and excavates as its dwelling-place a more or less cylindrical gallery, almost half an inch in diameter, in moist ground, the direction of which is usually at first horizontal and then vertical for a greater or less part of its length. The interior of this domicile the Spider lines with a compact tube

CTENIZA FODIENS AND ITS NEST.

of silk; but instead of closing its aperture with a trap-door, the nest is finished by continuing the lining-tube beyond its mouth for a greater or less distance, the part thus left free lying upon the surface of the ground. The female deposits her eggs, which number from thirty to forty, in a silken cocoon, which she attaches to the inner extremity of her nest.

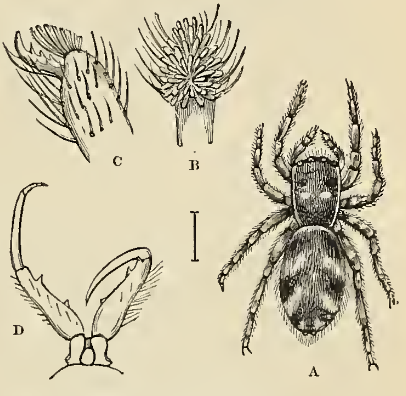
TRIBE II.—DIPNEUMONES.

The Dipneumones, as indicated by their name, possess only a single pair of lung-sacs, and the base of the under surface of the abdomen shows only a single pair of the opercula closing their apertures. The tracheal system has its apertures either immediately behind those of the lung-sacs or near the end of the abdomen. These Spiders, however, have another distinctive character in their falces, which may be placed either vertically or in an inclined plane, but always have the claw-joints articulated so that they bend in towards the middle line of the body.

FAMILY II.—SALTICIDÆ, OR SALTIGRADÆ.

The first two families of this tribe have the eyes nearly always placed in three transverse rows upon the surface of the cephalothorax. That is to say, we may distinguish two rows of two each and a third containing four, although in many cases an imaginary line may be recognised as combining the two separated pairs into a single curved row. In the Salticidæ the general form is compact, and the cephalothorax of nearly equal width from back to front, so that its shape is more or less rectangular. The legs are comparatively short and stout, and usually terminated by a pair of claws, below which there is a bunch of hair-like papillæ, termed a *scopula*, although sometimes this organ is wanting, and there are three claws. The extremity of the abdomen has three pairs of spinnerets.

The Salticidæ are generally neat and active-looking Spiders, of small or moderate size. The species are exceedingly numerous, and distributed in all parts of the world. Those of warm climates include the largest forms, and many of them display a remarkable brilliancy or iridescence of colouring. They are of wandering habits, preparing no snares for the capture of the flies and other insects on which they feed, but prowling about in search of their prey with a most extraordinary cat-like stealthiness, and often capturing it by means of a sudden spring. Their habit of making little jumps under such circumstances, and even when merely alarmed, has caused the family to receive the name of Saltigradæ, and is also alluded to in the name of the typical genus *Salticus*, upon which the family name Salticidæ is founded. They are to be found upon the trunks and leaves of trees and bushes, on railings, and about rocks and walls, in fact, wherever the flies which constitute their principal nourishment are to be met with. At the approach of danger they take shelter in holes and crevices, or throw themselves off and drop to the ground at the extremity of a fine silk thread, which it will be found they drag behind them, and attach from point to point all the while they are engaged in their predatory wanderings. This habit may be easily observed during the summer in the case of the commonest of our British species (*Salticus scenicus*), which may be met with almost everywhere in abundance, running about in the hot sunshine upon brick walls, palings, and the trunks of trees, and even upon the iron railings of balconies and other parts of houses in London itself. This interesting little creature, which is about a quarter of an inch long, and black, with white interrupted transverse bands, has a singularly alert look when engaged in its search for prey. Nevertheless, it moves everywhere with the greatest circumspection, and occasionally, by straightening the fore legs, elevates the front of the cephalothorax, in which we find a pair of enormous eyes, so as to obtain a wider range of vision. Its progress upon smooth and perpendicular surfaces is facilitated by the scopulæ, or tufts of adhesive hair-like papillæ placed at the extremity of each foot; and when by this cautious method of approach the Spider has arrived near enough to its intended victim, by a sudden rush and spring the latter is at once seized and soon destroyed. Upon thin iron railings we have seen this Spider advance along the lower surface of the



SALTICUS SCENICUS.

A, female, enlarged; B, foot from below with scopula; C, foot from the side; D, falces of male.

rail towards a fly sitting unsuspiciously on its upper surface, and peeping up from time to time to see whether it was yet near enough for the final spring, the whole behaviour of the creature reminding one forcibly of the conduct of a cat similarly occupied in pursuit of a mouse or bird. In June, the female constructs one or two cocoons of white silk, containing as many as fifteen or sixteen eggs, which are not agglutinated together. These cocoons, which are of a slight texture, are then enclosed in a compact cell made of white silk in the crevices of rocks, walls, and the bark of trees.

FAMILY III.—LYCOSIDÆ, OR WOLF SPIDERS.

The Lycosidæ, Wolf Spiders, or Citigradæ, like the preceding, are wandering predaceous Spiders, but they run down their prey without springing upon it after the fashion of the Salticidæ. Their ocelli are generally placed in three rows, and the cephalothorax is robust, but this part of the body is narrowed towards the front; the falces are placed vertically; there are three pairs of spinnerets; and the legs taper to the extremity, and are usually terminated by three claws, without any scopulæ or adhesive hairs, although some species have only a pair of claws, assisted by a small scopula at the end of each tarsus. Although inferior in size to the Mygalidæ, they are generally larger than the Salticidæ, and many of the tropical, and especially American species, exceed an inch in length of body. They take up their abode under stones, in the crevices of rocks and of the ground, in moss and under fallen leaves, and wander about, especially at night, in pursuit of the insects which constitute their chief food, and which they capture principally upon herbage and low bushes. Many of the species live among woods and on dry commons, but some seem to show a preference for marshy places and the neighbourhood of water, often even running upon the surface of pools, and making their way below the surface by crawling down the stems of aquatic plants. They can remain thus submerged so long as the air confined among the hairs covering the body will serve them for the purpose of respiration. While running on the surface of the water these Spiders freely seize the insects that come in their way, and one British species has received the name of *Lycosa piratica*, from its having this habit, which, however, is common to many others, and to some species of the allied genus *Dolomedes*, such as *D. fimbriatus*, a large and handsome Spider, attaining a length of five-sixths of an inch, that abounds in the fen country.

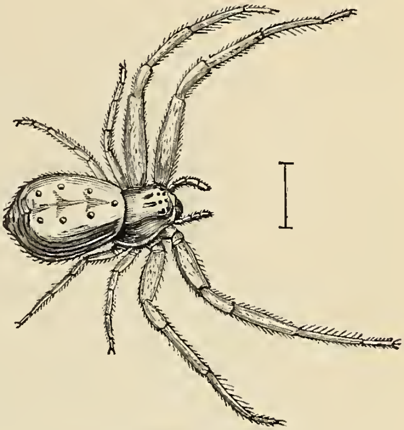
DOLOMEDES MIRABILIS.
Female, with egg-bag, enlarged.

Notwithstanding their well-earned character for ferocity, these, like most Spiders, show a most affectionate care for their offspring. The *Lycosæ*, and some others, place their eggs, from the number of fifty to over one hundred, in a small, flattened, silken case, resembling two saucers put together by their edges, which they then attach to the under side of the extremity of the abdomen, and carry about with them. The female of *Dolomedes* places a still larger number (from two hundred to two hundred and fifty) in a rough-looking, globular cocoon, which she also carries about, holding it under her sternum by means of the falces and palpi, but at the same time attaching it to the spinnerets by a couple of strong threads. When the young Spiders are about to be hatched, the mother spins a dome-shaped web among low herbage, and under this the newly-hatched young cluster together on lines which they spin for their own accommodation, and remain there, carefully tended by their parent, until they have become able to shift for themselves. The most celebrated species of the family is the Tarantula (*Lycosa tarantula*), varieties of which, or of distinct, but very nearly allied species, occur throughout southern Europe. In some parts, notably in Italy, the bite of these large Spiders, which exceed an inch in length, is supposed to produce most remarkable effects, including a sort of epidemic dancing madness; but it would appear that, although their bite may give rise to disagreeable symptoms, the stories told by the older writers are much exaggerated.

FAMILY IV.—THOMISIDÆ, OR CRAB SPIDERS.

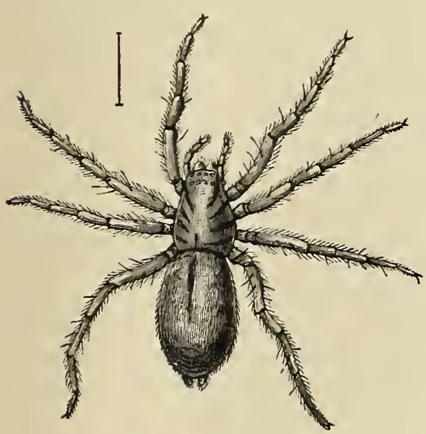
The Thomisidæ constitute the first family in which the eyes are placed in two rows upon the surface of the cephalothorax, and these rows are generally curved, sometimes in parallel lines, the first row sometimes more convex. The first two pairs of legs are generally longer and stouter than

the rest, and in the typical portion of the family the front pair are pushed forward quite to the fore part of the cephalothorax, and the whole body shows a generally broad and depressed form. They usually possess only two claws on each foot, associated with a few adhesive hairs, which sometimes form a small scopula. The peculiar short-bodied form and large arms of these Spiders have led to their being called "Crab Spiders." The name of Laterigradæ, also given to the family by some writers, alludes to their frequently running sideways, like Crabs, a movement which is facilitated by the great development of the first two pairs of limbs.



THOMISUS CITREUS.
Enlarged; the line shows natural size.

The species of Thomisidæ are exceedingly numerous and very widely distributed, but they seldom run to a large size. Among the British forms a length of a quarter of an inch is considerable, but the American species are as a rule larger. The finest British species (*Sparassus smaragdulus*) is half an inch long in the female sex, which is of a fine green colour. The male is also green, but banded longitudinally on the back of the abdomen with crimson and yellow. They usually conceal themselves among herbage and in flowers, but sometimes in cracks and crevices of trees, rocks, and walls, or even in cracks in the ground and under stones. It is in these situations that they lie in wait for the insects which constitute their prey, which they sometimes seize by surprise on their coming close to the lurking-place, especially in the case of the flower-haunting species, and sometimes pursue with great agility. The females deposit their eggs, which vary in number from about thirty to two hundred or more, in a small compact cocoon of silk, usually of a lenticular form, like those of the *Lycosæ*. These are sometimes, but rarely, attached to the lower surface of rocks and stones; generally the leaves of plants are selected for their reception, and these are either drawn together or bent at the edges, so as to form a protective covering for the cocoons. When alarmed, the Spiders of this family often adopt the crab-like device of simulating death to elude danger, and in this helpless attitude the species here figured may often be detected lying in the hearts of flowers, where its yellowish coloration renders it very inconspicuous. The young Spiders of this family are among those most addicted to float through the air on a support of gossamer in fine autumn evenings.



DRASSUS CUPREUS.
Enlarged; the line shows natural size.

FAMILY V.—TEGENARIIDÆ OR TUBITELÆ.

In this extensive and varied family, of which the common House Spider may be taken as a typical example, we again find the eyes placed in two rows, but they vary somewhat in arrangement. The first and fourth pairs of legs are longer than the second and third, and all the legs taper towards the extremity, where they are generally terminated by a pair of claws, accompanied by papilliform hairs, which sometimes form a small scopula. In some cases there are three claws. All the Spiders of this family weave a more or less complete web for themselves, usually consisting of numerous threads sometimes united into a sort of sheet, but nearly always connected with a more or less tubular portion which serves as a dwelling-place and shelter for the Spider.

The DRASSIDES, a series generally of small Spiders of compact form and active habits, have three pairs of spinners, and generally only two claws on the tarsi, supplemented by numerous papillary hairs, which sometimes form scopulæ. They are numerous in most parts of the world, and reside in silken cells which they build for themselves in the crevices of rocks and walls, among leaves, and under the loose bark of trees. In similar situations, or

attached to stones, the female deposits her eggs, to the number of forty, fifty, or more, in a firm and compact cocoon of white silk, about which, or within a light outer web surrounding it, the parent Spider remains in attendance on her progeny. This is especially remarkable in the case of some species which bury their cocoons in the earth, and these, as well as the species frequenting leaves, herbage, &c., often enclose the cocoon in a looser silken web, which serves the female as a habitation. The most remarkable of all the species, however, is the Water Spider (*Argyroneta aquatica*), which passes the greater part of its life beneath the surface of the water, pursues its prey and even constructs its nest in this abnormal situation for an air-breathing Arthropod. The Water Spider is about half an inch long, and what is a remarkable circumstance the male is larger than the female. The cephalothorax and limbs are of a dark reddish-brown colour, and the abdomen, which is ovate, olive-brown. When swimming under water the numerous hairs with which the latter part is clothed carry down a supply of air in their interstices, and it is by means of this that the Spider is enabled to breathe. This air gives it a silvery appearance when swimming. Not content with this arrangement, which necessitates constant visits to the surface for fresh supplies of air, the Water Spider builds itself a dome-shaped cell, attached by silken threads to neighbouring objects in the water, such as sticks and plants, then by fetching down from the surface continual supplies of air and discharging them beneath the dome-like web, the latter gets inflated with air after the fashion of a diving-bell, and the little architect has a safe and comfortable dwelling in which it can rest freely for a longer or shorter time. The Spider appears to hibernate in its subaqueous dwelling, and also to deposit its cocoon of eggs there.

The Dysderides are nearly related to the preceding, but have only six eyes, and a curious West Indian genus belonging to the group (the genus *Nops*) has only a single pair of rather large eyes placed far from the front margin of the cephalothorax. They are rather elongated, but strong and active Spiders, usually with large and powerful falces, and reside in cells and tubes of silk placed under stones and in crevices of rocks, walls, and the bark of trees. From these habitations they rush out upon passing insects, which they take by surprise. The species are not very numerous, but are widely distributed. Several are recorded as inhabitants of Britain.

ARGYRONETA AQUATICA.

The Scytodides, which also have six eyes, have a rather shorter and rounder body, and proportionately longer legs than the Dysderidæ. They inhabit temperate and warm countries, chiefly in the Old World, and they are found in caves and houses, as well as under stones and among herbage. Their spinning is generally feeble, and they produce only a few irregular lines.

The Ciniflonides are a small sub-family, the known species of which are inhabitants chiefly of Europe, North America, and South America, but are represented also in the Atlantic islands. Mr. Blackwall distinguishes them by the possession of eight spinnerets, the fourth pair being placed quite at the base of the spinner, and consisting of a couple of very short, truncated, conical bodies of oval section, united to each other for their whole length. They are further characterised by having a peculiar organ, called a *calamistrum*, upon the first tarsal joint of each posterior leg. This consists of two close, parallel rows of short, movable spines, which are employed by the Spiders in the construction of their very singular snares. These Spiders live in the crevices of rocks, walls, and the bark of trees, and among the leaves of trees and plants, and, in the neighbourhood of the places of their abode, they prepare their curious toils, composed of silk combed by the calamistra.

into a dirty and shabby-looking material, curled and twisted into the semblance of an exceedingly loose, irregular, open network of extremely fine threads, usually supported upon a straight line of greater strength. This fine, loose material clings with remarkable tenacity to whatever it touches. The eggs of *Ciniflo atrox*, a common British species, are placed, to the number of about seventy, in a loose white silk cocoon of plano-convex figure, which is attached to the inner surface of an oval cell, composed of curled silk, disfigured on the outside by fragments of dirt of various kinds. The species of *Ergatis*, two or three of which occur in Britain, live generally upon heath and furze, the extremities of the twigs of which they surround with a loose, whitish web serving for the capture of their small prey, while, at the proper time, the female conceals within this web, upon which the remains of her victims are hanging, two or three lenticular cocoons, with from ten to thirty eggs in each.

The Common House Spider, and some allied forms, constitute the last sub-family of this group, that of the Agelenides, which are generally rather large, powerful Spiders, with the legs and usually the hindmost spinnerets long, and the eyes nearly always in two curved rows with the concavity forward. Under the common name of the House Spider are apparently included at least two species, *Tegenaria domestica* and *T. civilis*, the former rather more and the latter less than half an inch in length of body. There is considerable resemblance between them, but the legs of *T. domestica* are a good deal longer in proportion than those of *T. civilis*. With regard to the latter species, it has been ascertained that both sexes change their skin nine times, once within the cocoon and eight times after quitting it; that they live for four years, and the female after a single impregnation can produce nine batches of prolific eggs; and that limbs removed at the coxa will be reproduced six times at the succeeding changes of skin. The habits of the two species are very similar. They inhabit old neglected buildings, outhouses, &c., taking up their abode in the corners formed by walls, roofs, and rafters, where they spin a more or less horizontal sheet of web, from which many fine lines are given off to adjacent objects both above and below, while, in the most sheltered part of the corner, it communicates with a short tubular cell in which the Spider resides. The eggs are deposited in lenticular cocoons of white silk, each again enclosed in a silken bag, the outer surface of which is disguised by morsels of plaster and other rubbish.

The species of *Agelena*, several of which are found in Britain, live out of doors in woods and heaths, but they also produce a sheet-like web, furnished with a cylindrical tube for the Spider's dwelling-place. The commonest species (*Agelena labyrinthica*), is found generally upon heaths and waste ground, where its large cobwebs are often striking objects upon the heath and furze. The cocoons of the female are lenticular, contain from 50 to 120 eggs, and measure nearly half an inch in diameter; there are usually two of them, and these are enclosed in a large sac of compact white silk, to the interior of which the cocoons are attached by silken lines so compacted together as to have been compared to short pillars. The cocoons or their containing sac are often disguised with dirt, as in the case of the House Spider.

THERIDION NERVOSUM.
Five times natural size.

FAMILY VI.—THERIDIIDÆ.

This is a very extensive family of Spiders, usually of small or moderate size, having the abdomen generally large in proportion to the cephalothorax, and of a broadly ovate form, especially in the females, and the fore legs usually the longest of all. The eyes are arranged in two transverse rows, but sometimes in part elevated upon tubercles or other processes of the upper surface of the cephalothorax, and the tarsi have three claws at their extremity, frequently associated with others of very minute size. The species of this family are most numerous in temperate climates, and the greater number of the known forms belong to the Eastern Hemisphere. Many of them are adorned with elegant patterns, and display considerable variety of coloration. They inhabit the foliage of trees and shrubs, herbage, clefts and cavities in rocks and walls, and the interior of buildings, and are sometimes to be found under stones on the surface of the ground. In the more exposed situations they generally construct irregular snares, composed of fine threads crossing each other in all directions, whence the name *Inæquitelæ* has been applied to the family.

The females deposit their eggs in cocoons of various forms generally attached to some object

in the neighbourhood of the snare, or even within a slight protective web. Sometimes the cocoon, of a more or less globular form, is affixed to the under surface of the leaves of trees and shrubs, the edges of which are joined and more or less brought together by a loose tissue of silken threads, forming a sort of nest, in which the female may remain for a considerable time with her progeny after the latter are hatched, and actually supply them with food. *Theridion tepidariorum*, a species which has only been observed in Europe in conservatories, makes several pear-shaped cocoons, and suspends them by the narrow ends within a dome-shaped upper part of the snare; and the balloon-shaped cocoon of *Theridion variegatum*, as described by Mr. Blackwall, "is composed of soft silk, of a loose texture and pale brown colour, enclosed in an irregular network of coarse, dark red-brown filaments. Several of the lines composing this network unite near the smaller extremity of the cocoon, leaving intervals there through which the young pass when they quit it, and being cemented together throughout the remainder of their extent, form a slender stem, varying from one-tenth to half an inch in length, by which the cocoon is attached to the surface of stones and fragments of rock, resembling in figure and position some of the minute plants belonging to the class Cryptogamia." The cocoon itself is about an eighth of an inch in diameter. The curious species *Pholcus phalangioides*, which, although slender in its form, and endowed with limbs rivalling those of the Phalangiidæ in length, is nearly allied to the *Theridia*, forms a globular cocoon of slight texture, but of large size, which the female carries with her wherever she goes, holding it firmly by means of the falces.

The *Linyphiæ*, which seem to lead in some respects towards the next family, also construct a more regular snare than the typical *Theridia*. They make a fine sheet of web, stretched horizontally among the leaves and branches of trees and bushes, the herbage and other objects which form their ordinary shelter, and further held in position by fine intercrossing lines stretched from its surface to neighbouring points of support. These Spiders take their place to lie in wait for prey on the under surface of the web, and they immediately seize any insects which fall upon it; the intercrossing lines, especially those above the web, serving to check and throw down flying insects that may strike against them. Some species of the extensive genus *Neriene*, nearly all of which are very small, make snares similar to those of the *Linyphiæ;* others reside under stones. Many of them are noted as aeronautic species.

The species of the allied genus *Walckenaera* (or *Micryphantes*) frequently have the portion of the cephalothorax which bears the eyes more or less elevated or tubercular, and in *Walckenaera acuminata* this character attains an extreme development. In the female there is a truncated conical tubercle, having four eyes at its apex, and the other four in two pairs a little way down on the sides. In the male the eye-bearing process is of considerable length, upright and slender, terminating in a bilobed enlargement, each lobe of which bears two eyes, while the other eyes are placed in pairs upon the sides of a swelled portion about half-way down. This singular little Spider, which is about a sixth of an inch long, is found under stones and on rails in various parts of England. The species of *Pachygnatha* are remarkable for the enormous development of their falces, which are so large as to form a pair of stout divergent pieces at the front of the cephalothorax. *P. Clerckii* is a widely distributed British species, found under stones, &c.

Certain foreign species of this family share with the Tarantula in the evil reputation of being dangerously venomous creatures. They belong to the genus *Latrodectus*. The best-known species is the Malmignatte (*Latrodectus malmignattus*), which is almost half an inch long, and is common in the south of Europe and the islands of the Mediterranean, especially Corsica. It is a black Spider, adorned with about thirteen blood-red spots upon the abdomen. Its ordinary prey would appear to consist of rather large insects, such as Grasshoppers, which it is said to entangle and partially disable by means of threads stretched in various directions across the fields. Upon such insects the Spider inflicts a bite at the junction of the head and thorax, and the victim, if small, is said to die instantly, if large, to fall into convulsions, which, after a short time, terminate in death. The effect of the bite upon the human subject is also said to be very serious, as it causes much pain and fever, and, according to some writers, leads to fatal results. The same species, or a nearly allied one, occurs in Morocco, and is much dreaded. Its bite is also described as fatal; and two or three others are found in the Southern States of North America, of which similar tales are told. The female

Malmignatte is described as producing three large cocoons, each enclosed in a very compact and strong silken covering. They contain a diminishing number of eggs, the first produced having 400 and the last about 200.

FAMILY VII.—EPEÏRIDÆ.

In this family we have to do with the most familiar of all Spiders, the Garden Spider, whose beautiful geometrical webs force themselves upon our attention in the autumn, and some allied species which chiefly inhabit the woods and hedgerows. All these Spiders have the first and second pairs of legs longer than the others, the tarsi terminated by three or more claws, with the additional

THE COMMON GARDEN SPIDER (*Epeïra diadema*).

ones very minute, and the eyes placed in two rows, with the two intermediate pairs generally larger than the others and forming a square figure, while the lateral ones are placed close together in pairs. In the British and European forms the abdomen, especially in the females, is of large comparative size, rounded or ovate and very convex. They all produce the vertical circular webs above alluded to, and hence the family has been called ORBITELÆ. The species are generally of considerable size, and some exotic forms measure over an inch and a half in length. They are very generally distributed over the face of the earth, and those of some tropical countries present very wide differences from the ordinary forms with which we are acquainted. They reside and construct their very ingenious snares chiefly among the branches and foliage of trees and bushes, but also frequent herbage, and sometimes avail themselves of the shelter of caves and buildings. The Spider resides and passes the winter in a dome-shaped silken cell formed in the neighbourhood of the snare, and usually connected directly with its centre by a strong line; and in similar cells the female encloses the cocoons containing her eggs, which are rather loosely constructed of silk, and of a globose or balloon-like shape. In some instances the Spider apparently encloses her whole stock of eggs in a single large cocoon. Thus Mr. Blackwall describes that of *Epeïra quadrata*, a well-known and very fine British species, as containing from 900

to 1,000 eggs; and the still more familiar *E. diadema* of our gardens similarly places 700 or 800 eggs in a single cocoon; whilst other species, including the widely-spread *E. apoclisa*, break up their store of eggs into detachments, and produce several cocoons, each containing about 200 eggs. The eggs are agglutinated together into a more or less lenticular mass, and the young Spiders, when first hatched, commonly spin a few lines, upon which they group themselves so as to form a compact little mulberry-like mass of living creatures, which disperse in the most extraordinary fashion if disturbed. The eggs in the cocoons are subject to the attacks of Ichneumons and other parasites.

The construction of the snares of the Common Garden Spider (*Epeïra diadema*) must be familiar to everybody. They consist of a number of stout radiating lines running from a common centre to a set of strong lines stretched between various neighbouring points of attachment, and enclosing the space occupied by the snare, and crossed by a series of short lines, which, as a whole, constitute a spiral running from the centre to the outer margin of the actual snare. The Spider commences its operations by stretching the outermost or foundation lines, which are attached to accessible points and then carried to other points and there fixed, the Spider sometimes dropping to the ground and walking across to the base of the opposite point of attachment, sometimes emitting a thread from its spinners, and allowing it to be carried away by the wind until it attaches itself to some object, and thus forms a bridge. These foundation lines are made strong, and the radiating lines are tightly stretched between them, and all joined at the centre of the future snare, and all these parts consist of simple smooth silken threads. The Spider then starting from the centre proceeds to stretch a series of short threads between the radii, in doing which it follows an absolutely spiral course around the centre, so that the short cross-threads are really arranged spirally, although, of course, each inter-radial piece is straight. But the most remarkable point is that the whole of these inter-radial pieces of thread, except those forming a few turns close to the centre of the snare, are of a totally different structure from the rest of the net. They consist of a slender elastic silk thread, covered with little beads of a viscous substance, which, no doubt, give them a greatly increased power of adhesion to any unfortunate insect that may come in contact with them. The central part, from which the viscous beads are absent, is the station in which the Spider lies in wait for its prey, hanging head downwards. Its shelter, as already stated, is a silken cell usually attained by a special thread, but sometimes only by one of the radii. This whole snare, or, at all events, all the viscid lines of the spiral, are renewed daily, and notwithstanding its complication the Spider occupies only about an hour in its fabrication.

It will be easily understood that a delicate net of this character stretched vertically in the air will capture many flying insects, and the owner, seated comfortably in the centre, is at once aware, by the shock produced upon its network and the subsequent struggles of the insect, that a victim is caught, and will further be able to judge of its whereabouts. To satisfy doubts upon this latter point, or to make a struggling prey entangle itself more thoroughly, the Spider will often, under these circumstances, shake its web violently; but it usually soon makes its way to the spot and effectually secures its prisoner by turning it round and round by movements of the legs, and at the same time swathing it in an abundant supply of silk, poured forth from the spinnerets. In this operation many species are aided by peculiar spines (called *sustentacula*) attached to the last joints of the posterior legs, which move in such a manner as to form with the claws regular claspers capable of drawing out silk from the spinnerets, and of performing various other functions in connection with that secretion. Mr. Blackwall describes the process in *E. diadema* as follows: — "Causing the victim to rotate," he says, "by the action of the third pair of legs and the palpi, the first pair of legs being also frequently employed in a similar manner, they extend the spinners laterally, and applying to them alternately the *sustentaculum* of each posterior leg, they seize and draw out numerous fine lines in the form of a fillet, which they attach to their revolving prey, and thus involve it in a dense covering of silk from one extremity to the other. By means of this stratagem," he adds, "they are capable of overcoming formidable and powerful insects, such as Wasps, Bees, and even large Beetles." It must be remarked, however, that these Spiders do not like Wasps in their nets, and have even been known to cut them carefully out and drop them to the ground.

The British and European species of this family are usuaally of nearly the same general form. The females have a large ovate or globose abdomen, the basal part of which projects high over the

surface of the cephalothorax, while the males have the abdomen more elongated and less convex. The males also are smaller than the females, and have the first and second pairs of legs more elongated, and as the connubial relations of these, as of other Spiders, are by no means upon what we should regard as a satisfactory footing in human society, and the female is usually quite ready to kill and feed upon her suitors, the actions of the male, as he ventures upon the web on which the object of his attentions dwells, are exceedingly diverting. He advances slowly, apparently feeling his way with his long fore legs, and the least movement on the part of the lady generally causes him to retire for

GASTERACANTHA ARCUATA.

the moment. The number of species is very considerable, and many of them show very fine colours, or an elegant pattern in their arrangement. The only British species that presents a striking peculiarity of form is the *Tetragnatha extensa,* a rather long, narrow species, resembling the *Pachygnathæ* of the preceding family in having long, divergent falces, and further distinguished by its habit of extending the legs before and behind nearly in a line with the body. It is nearly half an inch long, and is found in damp localities.

In the tropical part of both hemispheres there are a considerable number of species of this family which present great differences from those best known to us, especially in having the abdomen of a more or less horny texture, and produced into spines or processes often of enormous size. They form the genus *Gasteracantha,* and allied genera, which are particularly well represented in Brazil and other parts of tropical America. In their habits they resemble our Garden Spiders, and, like them, they spin a geometrical web.

CHAPTER II.

ORDERS ACARINA, TARDIGRADA, LINGUATULINA, AND PANTOPODA.

ACARINA—The Mites and their Allies—Characters—Classification—BDELLIDÆ, OR BEAKED MITES—TROMBIDIIDÆ, OR HARVEST MITES—HYDRACHNIDÆ, OR WATER MITES—ORIBATIDÆ, OR BEETLE MITES—GAMASIDÆ—IXODIDÆ, OR TICKS—ACARIDÆ, OR TRUE MITES—TARDIGRADA—LINGUATULINA—PANTOPODA.

ORDER III.—ACARINA.

THE innumerable host of the Mites and their allies, presenting an almost infinite variety in their organisation, constitute the order Acarina, the last order of Arachnida in which any special respiratory organs are to be recognised. Their respiration is effected solely by tracheæ. Their leading

characteristic is the amalgamation of the abdomen, which shows no signs of segments, with the cephalothorax, to form a single mass. The second pair of maxillary palpi, developed into a leg-like form, act as legs, and are counted as the first of the four pairs of legs with which the normal adult Mite is furnished. The mouth is constructed either for biting or for sucking. But the reader will see, even from the few descriptions and figures of animals of this order that we can here offer to him, that it is almost impossible to draw up a character of this order which shall strictly include all its members.

As already stated, the segments of the body are fused into a single mass, whence the name Monomerosomata has been applied to the order. Only in a few species a tranverse impressed line marks off the head, and, in a still smaller number, there is a similar indication of the hinder limit of the thorax. The cheliceræ, which represent the antennæ, are here, as in most of the preceding forms, the principal organs of the mouth. In the biting species they are permanently prominent, and terminated either by a claw or by a small nipper; in the suctorial forms, they acquire the form of hooks, needles, or minute saw-like organs, and are then protrusible from and retractile within a sort of sheath formed by the first pair of maxillæ, in conjunction with which they form a sucker. The palpi of the second maxillæ (labium) are, as already stated, developed into acting legs, and, including these, the mature Acarine has usually four pairs of limbs.

With regard to their internal structure, these animals are rather simple. The intestinal canal is short, running from the mouth to the anal opening, which, in most of them, is situated upon the lower surface, at some distance from the apex of the abdomen. In some cases it is almost a simple tube, but generally there is a more or less distinct stomachal part, from each side of which three blind tubes are given off. Except in the *Trombidia*, which have the intestine partly surrounded by a bunch of minute glandular bodies, there is no trace of the liver-like organ which attains such a development in the higher Arachnida; but the walls of the blind stomachal tubes are generally glandular, and may take the place of a liver.

As above stated, the Acarina are regarded as Arachnida with tracheal respiration, but in many, especially parasitic forms, no organs of respiration have yet been discovered, although from other characters presented by the creatures there can be no doubt that they are rightly placed in this present order. When respiratory organs have been detected they consist entirely of very delicate tracheæ, sometimes even destitute of the spiral thread which is characteristic of insect tracheæ, branching in a tuft from a main stem on each side. These main stems communicate with the stigmata, through which the air has access to the interior of the body, and these are generally only two in number, placed one on each side of the body, and situated either at the base of the chelicerae or in one of the hinder pairs of legs. The circulation of the blood appears to take place in the body-spaces, and no dorsal vessel has yet been discovered. The central nervous system, as might be expected from the general structure of the body, is much concentrated, consisting, in fact, of a single great ganglionic mass, traversed by the œsophagus, and giving off nerves in all directions. The Acarina are of separate sexes, and the internal sexual organs are sometimes rather complex. They open in the ventral surface, often far forward. Nearly all lay eggs, but the species of the family Oribatidæ produce living young. In most cases the young quit the egg under a form more or less different from that of their parents, and in attaining to the latter many of them pass through transformations which may be regarded as, to some extent, analogous to those of insects. The main difference consists in the absence of one pair of legs, which does not make its appearance until after a change of skin, and frequently a resting or pupal stage, in which the immature animal is generally parasitic in its habits.

The Acarina, which are all of small size, and many of them of microscopic minuteness, are, as might be expected, of universal diffusion over the face of the globe, and their distribution in any given country is equally universal, while the functions they perform in nature fulfil nearly every office that creatures so small are capable of. Some inhabit the water, and even the sea has its Acarine inhabitants; others, the great majority, live on land or on plants of various kinds. Many are parasitic both upon and beneath the surface of other animals; others are predaceous, seizing and devouring such little creatures as they are able to overcome. Some again feed upon living vegetable matters, and many of these give rise to gall-like deformations of the parts of plants that they

attack; whilst others do not disdain dead, and even dried animal and vegetable materials, and thus act the beneficial part of scavengers. In a fossil state Acarina are known only as inclusions in amber.

The Acarina may be divided into seven great families, some of which, however, include a considerable variety of forms. The following tabular arrangement will serve as a guide to their general characters :—

I. Forc part of head prolonged into a distinct beak, and separated by a constriction from the rest of the body	1.—Bdellidæ.
II.—Fore part of head not prolonged into a distinct beak.	
A. Skin firm.	
1. Skin scarcely extensible; palpi not seated on a common chin-piece.	
a. Cheliceræ claw or needle-like.	
* Palpi terminated by a pair of nippers	2.—Trombidiidæ.
† Palpi with bristles or a hook at the extremity . . .	3.—Hydrachnidæ.
b. Cheliceræ with nippers.	
* First joint of palpi very large	4.—Oribatidæ.
† Joints of palpi nearly equal	5.—Gamasidæ.
2. Skin leathery, very extensible; palpi attached to a chin-plate . .	6.—Ixodidæ.
B. Skin soft, with a few chitinous bands	7.—Acaridæ.

FAMILY I.—BDELLIDÆ, OR BEAKED MITES.

In these there appears to be a distinct head, separated by a constriction usually resembling a short neck from the rest of the body, but this projecting beak apparently consists only of the mouth, and the eyes, when present, are situated behind the constriction. The latter organs vary in number from two to six. The cheliceræ terminate in nippers; and the first pair of palpi are long and slender, composed of five joints, and generally more or less elbowed at the end of the second joint. These are small Mites, usually of a bright colour, slow in motion, and living in damp ground. The young resemble their parents. The best-known species is *Bdella longicornis*, which is about one twenty-fourth of an inch long, scarlet, with four eyes. These Mites appear to be predaceous in their habits.

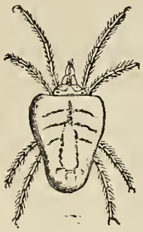
FAMILY II.—TROMBIDIIDE, OR HARVEST MITES.

This is a much more extensive family than the last, with which, however, it has much in common. Its members never display the separate head-like part characteristic of the Bdellidæ, and the first palpi are short and stout, but their termination shows two opposite pieces, one of which is a claw. The cheliceræ do not end in nippers; and the legs consist of six or seven joints, and are terminated by a pair of claws. These Mites are generally of some shade of red, often of the brightest vermilion, but sometimes more or less spotted with brown or black. They live upon the ground, and among plants, and many of them run very fast. The young are six-legged, but otherwise like their parents. Many of them pass through a parasitic stage.

A considerable number of these Mites are vegetable feeders, and some of them occasionally do a good deal of mischief to various plants and trees, of which they frequent the under sides of the leaves, pricking the tissues with their sharp cheliceræ, and sucking out the fluids. One of the commonest species is well known as the Red Spider (*Tetranychus telarius*), although it varies a good deal in colour, apparently with age; but the majority of the specimens are of a brick-red. It is found upon a great variety of plants and trees in our gardens, spinning an exceedingly delicate web, under which a whole colony of all ages lives in security. Other species of the genus *Tetranychus* and its allies also abound upon many cultivated and wild plants. The young form of one species, which appears to be a *Tetranychus*, is the well-known "Harvest Bug," which torments tender-skinned people so seriously if they wander in country places in the autumn. The Mite that penetrates the skin is the six-legged form, and has been described under the name of *Leptus autumnalis*. It attacks not only human beings, but dogs, cats, and many other animals. The best remedy for the itching it produces is to rub the part affected with some essential oil.

The Scarlet Mite (*Trombidium holosericeum*) may serve as the type of a large group of Mites belonging to this family, but of carnivorous habits. It is about a twelfth of an inch long, with

a squarish pear-shaped body, upon which two parts may be recognised, a small anterior and inferior portion bearing the eyes, the organs of the mouth, and the first two pairs of legs, and a larger posterior portion, on the under surface of which, at some distance from the others, the third and fourth pairs of legs are situated. The whole Mite is of a bright scarlet colour, and the larger hinder part shows a beautiful velvety texture. This Mite may be often seen running about upon the ground, in moss upon the roots of trees, &c., and it is exceedingly rapid in its movements. In a young stage, it passes a certain period as a parasite upon the long-legged Harvest Spiders (*Phalangium*), usually selecting the females, and attaching itself behind the hinder coxæ, where it is out of reach. In this situation it remains, although capable of some amount of movement, and its six legs advance more and more towards the front as the animal grows. When detached from the Harvest Spider, it conceals itself in the ground, and becomes an oval nymph, within the skin of which the eight-limbed perfect Mite may be watched in process of formation. The change takes about three weeks. Other species of the group attach themselves to insects of various kinds to undergo this nymphal change, and, as all of them attack and destroy Aphides, and other minute insects, they must be regarded to a certain extent as our friends.

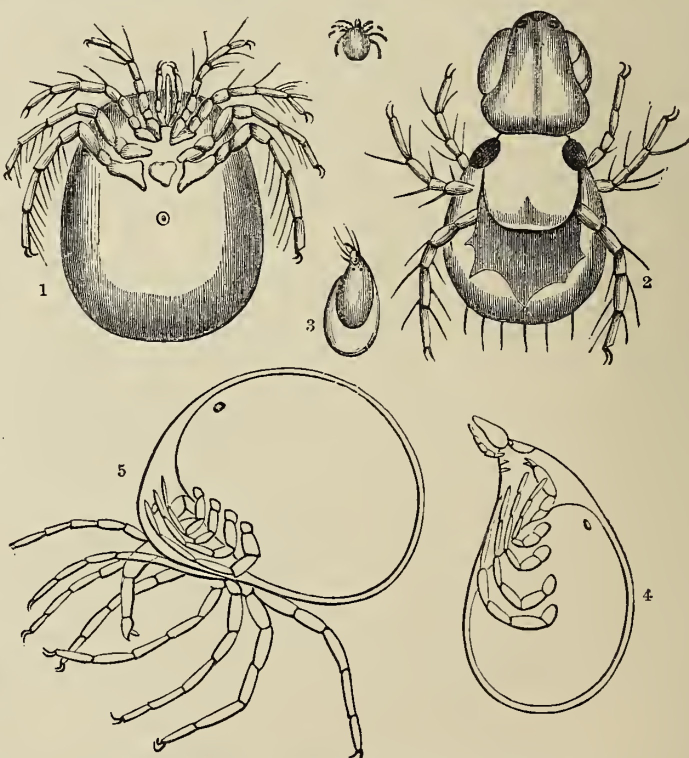


TROMBIDIUM HOLOSERICEUM.

FAMILY III.—HYDRACHNIDÆ, OR WATER MITES.

These creatures may be regarded as aquatic representatives of the *Trombidia*, as they resemble these in many characters. They have usually a more globose form of body, and there is no trace of its division into two parts; the cheliceræ are similar; the palpi terminate in hooks or bristles; and the legs, which generally increase in length from the first to the fourth pair, are strong and fringed, and terminated by a pair of claws. They have two ocelli on the fore part of the body.

These Mites, which are generally of tolerable size for their order, a sixth of an inch being a common length, live habitually in water, many of them swimming with great ease and considerable rapidity, while some prefer crawling upon the bottom. Some of them even live in the sea. Although they remain constantly under water, and apparently never come to the surface to breathe, they possess no recognisable branchial organs, but are furnished with the usual tufts of tracheæ, opening by stigmata placed between the fore legs. Under these circumstances it is rather difficult to understand how they carry on their respiration, and some naturalists have suggested that their tracheæ must be enabled to respire the air dissolved in the surrounding water. Of this, however, there is, we believe, no evidence. The young differ very materially from their parents. Like other young Mites they have only three pairs of legs, but they are also provided at the fore part with an enormous suctorial organ, by means of which they attach themselves as external parasites to aquatic insects of all sorts.



THE METAMORPHOSES OF HYDRACHNA GLOBULUS.

1, The perfect mite, natural size and magnified; 2, the larva, magnified; 3, a nymph; 4, a nymph, magnified, showing the eight-legged mite within; 5, the last form of nymph, magnified.

In this parasitic condition, deriving nourishment from the fluids of their hosts, they gradually increase in size, and at length, after a period of quiescence, undergo the change into the adult form within the skin which has covered them as larvæ. In this mature state they are generally handsome little creatures, glorying in bright colours, especially red, and frequently adorned with black or brown markings. As parasites they may be found commonly upon the larger Water Beetles, the Water Scorpion (*Nepa*), and especially the species of *Gerris* which run upon the surface of the water. Some species appear to become parasitic in Molluscs when adult, and one of these (*Hydrachna concharum*) has been supposed to cause the formation of pearls in fresh-water mussels by the irritation that it causes in the mantle.

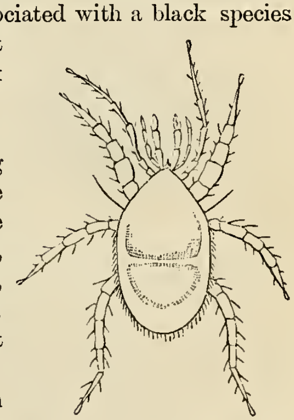
One or two species which appear to belong to the present family have been found swimming in the sea, and form the genus *Pontarachna.* Examples have been met with on both sides of the Atlantic and in the Mediterranean. Besides these, several species of marine Mites of more doubtful relationships have been obtained on our own and other coasts, partly by dredging and partly by the investigation of rock-pools on the shore, and these may be mentioned here, although most of them appear to be more allied to the following family. Special attention was first called to them by Mr. Gosse, who met with examples at Ilfracombe, and the late Mr. Andrew Murray was inclined to place them in a separate family, which he names HALACARIDÆ, from the name (*Halacarus*) given by Mr. Gosse to one of his genera. As general structural characters of his proposed family, Mr. Murray says that they have either a stiff or a more or less rigid cuirassed skin, and their legs springing from the outer margin of the body.

FAMILY IV.—ORIBATIDÆ, OR BEETLE MITES.

This family consists chiefly of ovate or globular Mites covered with a hard and shining skin, so hard and shining in many cases as to remind one of a Beetle. They have retractile pincer-like cheliceræ; and the first joint of their short four-jointed palpi large, and converted into a masticating organ. They have no eyes, and the tarsi are terminated either by one or three claws. These are all terrestrial Mites, generally of small size, although some of them attain the bulk of an ordinary pin's head. They appear to be vegetable feeders, although this is not quite certain, as they occur in moss and under the bark of trees, where minute animals abound; but some species have been observed to bore into rotten wood, and apparently feed upon it. Their colour is generally dark brown, or nearly black, and the cephalothorax is often dilated at the sides, and sometimes provided with a pair of cup-shaped stigmata. In the young state there would appear to be an approximation between these Mites and the Acaridæ, as Professor Claparède found associated with a black species (*Hoplophora contractilis*) a soft white Mite, like a Cheese Mite, and it seemed clear that this was a stage in the development of the black Oribatid.

FAMILY V.—GAMASIDÆ.

This family includes a great number of small, eyeless, horny-looking Mites, which may be found free upon the ground and in moss, but are more frequently parasitic in their habits, living especially upon the surface of terrestrial insects of various kinds. They have nipper-like cheliceræ, free, nearly equal-jointed palpi, and legs generally similar in size and form, covered with hairs, and terminated with a pair of claws and a large pad. The skin is sometimes firm throughout, sometimes only in parts, the rest being soft and flexible as in the Acaridæ.



GAMASUS COLEOPTRATORUM.
Much enlarged.

Although parasitic in their mode of life, the Gamasidæ do not attach themselves to their victims by any permanent suctorial apparatus, but remain free and able to crawl about at pleasure, except that in one common species on Beetles, called *Uropoda vegetans,* the Mite fixes itself to the surface of its host by means of a sort of cord, the ends of which are attached to the Beetle and to the under surface of the Mite. This cord, which is neither horny nor tubular, would seem to be formed by the excrements of the Mite. A common and characteristic species is the *Gamasus coleoptratorum,* which also infests Beetles, and is one of those species in which part of the upper surface is not horny. The insects on

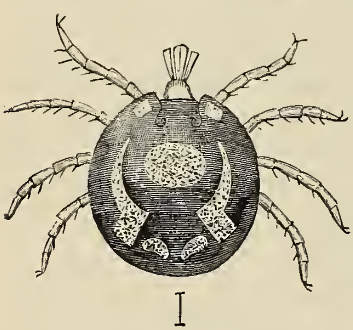
which they chiefly occur are such as burrow into the ground, in this country especially the common Dung Beetles (*Geotrupes*) and the Humble Bees.

Besides these well-known parasites of insects, the family includes several species which infest vertebrate animals, and are sometimes great plagues. One of the best known is the "Tick" (*Dermanyssus avium*) that infests domestic poultry, and also makes its way into pigeon-houses, and even into the aviaries and cages in which small birds are kept. When numerous, these parasites are often injurious and even destructive, especially when they attack small birds; and they will also transfer their operations to the bodies of human attendants on their natural victims, sometimes with very disagreeable results. Several other species of *Dermanyssus* and allied genera live parasitically upon Bats, and some of these present most remarkable characters.

FAMILY VI.—IXODIDÆ, OR TICKS.

the Ixodidæ we have another family of parasitic Mites, some of which are well known in Europe under the name of Ticks, although it is in warmer climates that they most abound and attain their largest size. Some of them are indeed the largest of the Acarina, reaching a length of a third of an inch or more. They are more or less ovate or sometimes nearly circular in form, covered with a leathery and very extensible skin, part of which may, however, be horny; the palpi are small, seated on a chin-plate; the cheliceræ are retractile and generally serrated; the eyes are sometimes present, sometimes wanting; and the legs are similar in form, with two claws and a pad.

The sucking apparatus of these parasites is composed of the maxillæ and the cheliceræ. The former combine to form a sort of ring-like lower lip, from which the ligular portion extends forward as a grooved piece, the convex surface of which is furnished with reversed hooklets. The cheliceræ work in the groove of this piece, and can be pushed forward and retracted by the action of strong muscles, so as to perform the part of piercing organs, while their serrated margins assist in holding the parasite firmly to its victim. The quantity of blood drawn by these little pests from their hosts is by no means commensurate with their original size. The skin is so extensible that in many instances the full parasite increases to many times its original bulk, and when the victim is attacked by many such enemies at once the consequences may be serious. Although generally confined to some particular species or group of animals, the Ticks occasionally get upon the bodies of men, and are then very troublesome. Two species of the genus *Argas* (placed by many authors with the preceding family) are particularly noted as attacking mankind. One of these is the *Argas reflexus*, originally a parasite upon young pigeons; the other may be called the Persian Tick (*Argas persicus*), a species found in houses in some parts of Persia, and described as producing most serious effects upon those whom it attacks at night.



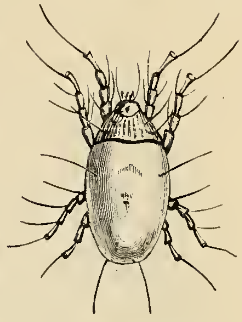
IXODES FLAVOMACULATUS.

Of the species of the genus *Ixodes* and the genera which have been separated from it, many inhabit woods, forests, hedge-banks, and herbage generally, and attach themselves to passing animals. Thus *Ixodes erinaceus*, a British species, is often found on dogs, foxes, hedgehogs, and cattle, and is known as the "Dog Tick;" another (*Ixodes marginatus*) is described as having swarmed in such great numbers in hay-fields as greatly to impede the operations of mowing and drying the grass. A few species are found on bats, but of those which are confined to particular animals the majority, so far as known, are parasites of different kinds of reptiles, especially snakes. They generally attack these near the eye. The species figured is parasitic on a West African *Python*.

FAMILY VII.—ACARIDÆ, OR TRUE MITES.

This last group includes all the Mites that have not been cut off from the original family Acaridæ to form special families, and hence its members naturally show some little divergence of character. They are all minute and very lowly organised Arachnida, and their skin throughout is thin and membranous, with here and there a harder band for the support of the limbs. The cheliceræ are nipper-like, or pointed, and in the latter case capable of being retracted into a sheath; there are no eyes; and the legs are either mere stumps, or produced and terminated by an adhesive vesicle.

In their habits, as in their structure, they are most various. Thus a considerable number, of which the common CHEESE MITE (*Tyroglyphus domesticus*) may be taken as the type, live either in dry or decaying animal and vegetable materials, or upon the roots of plants, such as Liliaceæ (between the scales), potatoes, dahlias, &c., or in Agarics. Cheese, flour, and sugar are also favourite substances with these little creatures. The members of the genus *Hypopus* and its allies, distinguished by having the two anterior pairs of feet fairly or well developed, while the two hinder pairs are small and concealed beneath the body, are found externally parasitic upon a variety of insects, and also occasionally upon vertebrate animals. *Hypoderas*, on the contrary, the species of which have a more or less elongated body, with two pairs of legs issuing from close to the anterior end, and two pairs from much farther back, includes internal parasites, some of them living under the skin, or in the muscles of various vertebrate animals, and others in their bronchial tubes and lungs, or in the air-cells which exist under the skin in many birds. Occasionally these minute parasites occur in immense numbers.



TYROGLYPHUS DOMESTICUS. *Enlarged.*

A very considerable number of species, belonging to the genus *Sarcoptes* and its allies, are parasitic in the skins of various vertebrates, upon which they cause the disease commonly known in man as "the itch." They are generally of a broadly ovate or rounded figure, with the skin more or less distinctly striated across, and furnished with the usual four pairs of legs, placed half towards the front and half towards the posterior part of the body, the legs generally having several bristles, and terminating in a slender tarsal part with a sucker at the end. The chelicerae are nipper-like, and it is by the agency of these that the parasites burrow beneath the epidermis of the animals they infest. The species attacking human beings in Europe generally is the *Sarcoptes scabiei ;* but in Iceland and the northern part of Europe another form is so common that in some localities scarcely any of the inhabitants seem able to escape from it, and this produces a much more formidable complaint than the common Itch-mites. When the disease is allowed to proceed unchecked the parts of the body attacked by it become coated with a sort of crust, which is said to consist of the dead *Sarcoptes*, massed together by some viscid fluid, thus often simulating elephantiasis. Allied forms attack the fox, dog, cat, goat, pig, rabbit, fowl, horse, ox, and other quadrupeds and birds. Besides, there are a good many louse-like Mites, related to the preceding, which are found as surface parasites upon mice, bats, and birds, in various countries. These sometimes have the tarsi terminated by curved claws, which assist them in clinging to the hairs of their victims. Most of them have sucking mouths, but some appear to be organised for biting. In connection with these parasites we may mention the curious species *Demodex folliculorum*, a microscopic, worm-like creature, closely ringed throughout, furnished towards the anterior end with four pairs of very short limbs, each of which terminates in two claws. The mouth is suctorial. The larva has only three pairs of legs. This singular little parasite occurs pretty frequently in the hair-follicles and sebaceous glands of the skin in man, where it often gives rise to pimples, from which it may be squeezed by a careful application of the nails. It is, no doubt, the "maggot in cheese-monger's nose" commemorated by Butler in "Hudibras," though we are not aware that it bestows its visits especially upon any particular class of tradesmen. A very considerable number of species referred to this family, and chiefly to the genus *Phytoptus*, attack the living tissues of plants, co-operating with the Aphides in their attacks upon the leaves and other growing parts, and, like them, often causing the formation of peculiar gall-like deformities and excrescences. The Mites, like the Aphides, generally attack the under side of the leaves, and cause them to grow up into hollow excrescences of various forms, in the interior of which the Mites live. Other allied species attack the buds of trees and materially injure their growth.

DEMODEX FOLLICULORUM.

ORDER IV.—TARDIGRADA.

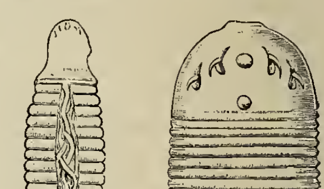
This is a small group of microscopic creatures commonly known as Bear or Sloth-animalcules, found in moss and in wet places, and displaying some peculiarities which have for a long time rendered them exceedingly interesting to microscopists. They have a longer or shorter oblong-

ovate body, with faint indications of four segments, and upon each side four short conical limbs, the hindmost of which occupy the posterior extremity. The mouth is suctorial, and consists of a fleshy tube containing a pair of styliform organs, which can be protruded and retracted by the action of muscles; and the legs are terminated by three or four claws. No organs of circulation or respiration are recognisable in them.

MACROBIOTUS HUFELANDI.

They have another peculiarity distinguishing them from all the other Arachnida, namely, that they are absolutely hermaphrodite; the single ovary containing its eggs being always visible in the hinder part of the body, and at the posterior end of it are placed the male organs, both sets opening into a dilatation of the intestinal canal. In the course of the latter we see towards the head a strongly muscular pharynx, followed by a very large intestinal sac nearly filling the body, and surrounded by many small dilatations, giving it a clustered appearance. The walls of this part are glandular, and no doubt perform the functions of a liver; and in addition to these there are two large salivary glands which discharge their secretion into the mouth. Curiously enough, the nervous system acquires a considerable development, having four large ventral ganglia with double commissures. On the sides of the head there are a pair of eye-points.

The systematic position of these curious little creatures was long a matter of dispute, although, so long since as 1785, the Danish naturalist, O. F. Müller, recognised their affinity to the Mites, and described a species under the name of *Acarus ursellus*. They live sometimes in water, but more frequently in moss in damp places, and some of them are found especially in a rather curious locality, namely, the gutters of the roofs of houses. Like the Rotatorial animalcules which also occur in such places, the Tardigrada have the power of resisting desiccation. They may be found apparently quite dry among the sandy dust of a gutter, and will revive at once on being duly moistened. Their eggs, as may be seen from the figure, are of large comparative size and few in number, and they are generally deposited simultaneously with a change of skin of the parent animal, so that the cast skin serves as a protection to the young animals in hatching. The young resemble their parents, but are only about one-third the size. The known species are not very numerous. That figured is found in moss, and measures about one thirty-sixth of an inch in length.



PENTASTOMA TÆNIOIDES.
A, female, natural size; B, male, natural size; C, head of male, enlarged; D, young larva, enlarged.

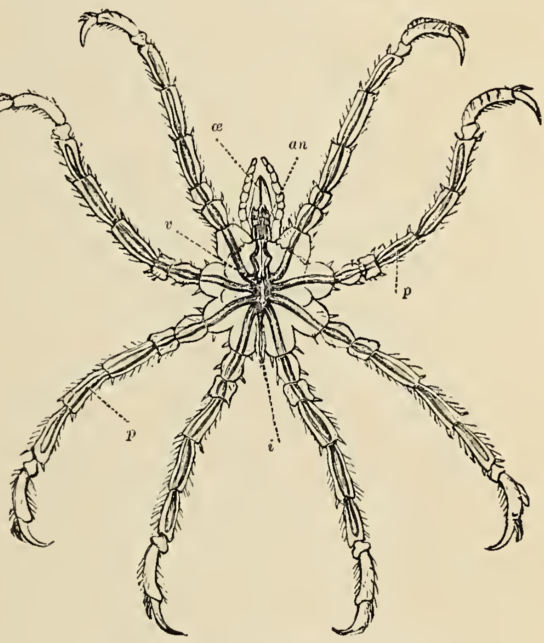
ORDER V.—LINGUATULINA.

If the *Demodex folliculorum*, which we have referred to the Acaridæ, be worm-like in its appearance, the same may be said with still more force of the creatures belonging to the present order, which indeed for a long time were always classed among the Entozoa. The knowledge of their development, however, showed that they too were most nearly related to the Arachnida, and of late years they have taken their place among the aberrant forms of that class.

In the mature state, the Linguatulina are vermiform creatures, with a distinctly-ringed, and usually flattened, body, having at the anterior end a mouth furnished with a horny ring, and on each side of this two horny hooks, which can be protruded from small apertures. Their form and the presence of these hooks led to the creatures being regarded as allied to the Tape Worms. The male is usually much smaller and shorter than the female. The intestine passes straight from the mouth to the other end of the body, where the anal aperture is situated. Of the central nervous system, the principal

part is a large ganglionic mass, forming a ring that embraces the œsophagus and gives off stems to various parts of the body; and no trace of respiratory organs can be detected, although, in some cases, there appear to be apertures in the skin representing stigmata.

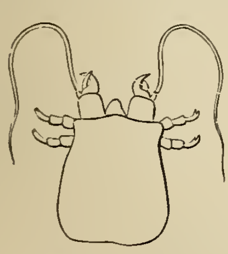
From the researches of Van Beneden and Schubarth it appears clear that the Linguatulina undergo a retrograde metamorphosis, and that while in the young state they show a distinct alliance with the lowest Arachnids, in their adult form they present strong resemblances to the parasitic worms, and it is curious that, like the latter, they have to migrate from one animal to another in order to attain their sexual maturity. The best known species (*Pentastoma tænioides*) is found when adult in the frontal and nasal cavities of the Dog and Wolf, where it doubtless causes much irritation. The eggs, when laid, are discharged with the mucus from the nose, fall upon plants, and are eaten with them by Hares and other mammals. The embryos hatched from these eggs, which show Arthropod characters, bore their way from the stomach into the liver, where they enclose themselves in a capsule, and change their skin several times. In about half a year they acquire the worm-like form, and again begin a migration, piercing through the liver, an operation which is sometimes fatal to their unfortunate host. Otherwise they again become encapsuled, and remain in this state until the animal containing them is devoured by some dog-like animal, when they at once make their way into the air-cavities, and wait there for their sexual maturity. This is the ascertained history of *Pentastoma tænioides*, and it is believed that the other species of the group have the same habits. The number of known species is about twenty, but more have been recorded owing to the individuals encysted in the liver or lungs of herbivorous animals being taken for distinct species. They form the single family Acanthotheca.



AMMOTHOA PYCNOGONOIDES. (*Enlarged.*)
œ, rostrum; *an*, chelicerræ; *v*, stomach; *i*, intestine; *p*, *p*, blind tubes.

ORDER VI.—PANTOPODA.

This order includes a small number of curious marine animals which have been regarded by different authors either as Arachnida or Crustacea, and really seem in some respects intermediate between the two classes. They have a cephalothorax of four distinct segments, which constitutes nearly the whole of the body, the abdomen being represented only by a small rudimentary part seen between the bases of the hind pair of legs. No respiratory organs can be recognised, but a three-chambered heart has been detected in them. The legs, of which there are four pairs (the first pair representing palpi), are long and many-jointed, and in general they bear such a proportion to the body that the name Pantopoda (All-legs) applied to the order is peculiarly appropriate. The order has also been called "Podosomata," which expresses very nearly the same idea. The mouth is suctorial and forms a sort of rostrum, projecting in front of the cephalothorax. At the base of this, on the back of the cephalothorax, four eyes are placed on a tubercle.


LARVA OF NYMPHON.
Magnified.

In the interior the alimentary canal runs straight through the body, but the narrow stomach gives off on each side five blind tubes, which not only run towards the limbs as in the Arachnida generally, but actually traverse nearly the whole length of the legs, whilst the fifth (short) pair run up into the chelicerræ. The sexual organs are situated in a very singular position in both sexes, namely, in the fourth or

fifth joint of the legs, so that there are eight of them. In the females, however, the eggs are extruded from an aperture in the second joint, and passed from this to a pair of accessory limbs springing from the first segment beneath the first pair of true legs, and to these they remain adherent until the young are hatched.

The larvæ when just hatched possess an unsegmented body and only two pairs of jointed legs; their cheliceræ, which form nippers, often bear long lateral filaments, presenting a remarkable resemblance to the flagella of the antennæ in Crustacea, in fact, the little creatures may be well compared to the Nauplius form, as it is called, of many Crustaceans.

These very singular creatures are found in all seas, chiefly near the coasts, where they conceal themselves under stones, or cling to seaweed, and even to other animals. Occasionally they are met with adhering to fishes. In their movements they are slow and clumsy. A moderate number of species are known, generally of fair size, but in some deep sea dredgings large forms have been met with. They constitute two families, the Pycnogonidæ and Nymphonidæ.

The former (Pycnogonidæ) are generally of a more Crustacean aspect, and present a considerable external resemblance to certain Isopod Crustacea. They possess no cheliceræ or palpi. *Pycnogonum littorale* is a common species upon all European coasts, where it crawls about under stones and among seaweed, with masses of which it is not unfrequently found floating upon the surface of the sea. This species is nearly half an inch long.

The Nymphonidæ have pincer-like cheliceræ and palpi, and much longer legs than usually occur in the preceding family. The egg-bearing false-legs also are usually much longer than in the Pycnogonidæ, with which these animals agree generally in habits. The commonest European species (*Nymphon gracilis*) is about a quarter of an inch long. *Ammothoa pycnogonoides*, the species figured (p. 187), belongs to this family.

W. S. DALLAS.

CLASS CRUSTACEA.

CHAPTER I.

ANATOMY OF CRABS AND LOBSTERS.

Characteristics of the Crustacea—Their Mode of Existence—External Covering—Body Segments—Locomotory and other Appendages—Nervous System—Digestive Organs—Respiration and Circulation—Reproduction and Development—Metamorphosis—Exuviation—Reparation—Classification.

THE Crustacea, represented by the Crab and Lobster, and a great variety of other crust-clad animals with jointed limbs, form the fourth class of the *Arthropoda.* Most of the members of this class seem to be essentially fitted to live in water, being furnished with branchiæ or gills.

Taking the Common Lobster for an example, the entire body and legs are encased in a hard structure which is called the shell, but it is quite different from that of a Whelk or of an Oyster. Neither is it composed of the same material as our own bones, nor is it horny, but it is formed of a nitrogenous substance, insoluble in alkalies, termed *chitin,* arranged in layers, between which salts of lime (mainly the carbonate) are deposited.*

This shell serves the double purpose of a defensive covering to the softer parts of the animal, and also, by means of its overlappings, infoldings, projections, and rugosities, of giving attachment and support to the muscles which move the limbs and also to those of the internal organs, as the stomach, &c. In the common Prawn and Shrimp this shelly envelope is quite thin and translucent, and its structure can be seen under the microscope without preparation; but in the Crab the shell is often very dense and thick, and needs to be cut into thin vertical sections, or rubbed down, before its structure can be clearly made out with the microscope. If a thin vertical slice be prepared, three distinct layers or strata will be seen, namely, first, a horny structureless layer covering the exterior; second, a cellular stratum; and third, a laminated tubular layer. The innermost and even the middle layers may, however, be altogether wanting, as in some larval forms (*e.g.*, *Phyllosoma*), or as in the delicate covering of the Shrimp, in which only the cellular and horny layers are present.

Dr. Carpenter remarks: "In the Common Edible Crab (*Cancer pagurus*) we can readily separate the structureless horny outer layer, after a short maceration in dilute acid, thus leaving the middle cellular layer exposed, in the cells of which the *pigment,* or colouring matter, of the shell is contained. The thick inner layer may be best seen by means of a section perpendicular to the surface of the shell, when we can, with a magnifying power of 250 diameters, observe the parallel laminæ of which it is composed, and through which straight non-branching *tubuli* are seen to rise up at intervals through the cellular stratum forming little papillary elevations. It is from the thinness of the pigment matter in this layer, at these spots, that the coloured portion of the shell derives its minutely speckled appearance. In the shell of the Prawn we may notice the large star-shaped pigment or colour cells distributed over the surface, which, by concentration or diffusion of the colouring matter contained in them, tend to render them more like the sea-bottom which they frequent. In the Shrimps the cellular layer is not distinctly seen, whilst the calcareous portion forms concentric rings similar in structure to that seen in the papillæ of the surface of the deepest layer of the Crab's shell."

If any common Crustacean, such as a Lobster, Prawn, or Shrimp, be examined, it will readily be perceived that its body-covering is made up of a number of rings or segments jointed together, to which the feelers, claws, and legs are united by means of movable sockets. To give greater protection to the soft parts of their body, it often occurs, as in the Crab and Lobster, that a considerable number of these body-rings are soldered together into one piece, which may be compared to the back and breast-plate of a knight's armour. It was, however, discovered by naturalists long ago

* An analysis of the shell of the common Crab gives:—

Animal matter	28·6
Phosphate of lime	6·0
Carbonate of lime	62·8
Phosphate of Magnesia	1·0
Soda, salts, &c.	1·6
	100·0

that all these Arthropod animals have one pair of jointed limbs to each ring or segment of their bodies, consequently, if there be one ring, whether of extra size or no, having more than one pair of limbs attached to it, one is justified in at once concluding that this particular joint or plate is composed of several separate rings soldered together. And this conclusion is really borne out by a study of the general structure of the class, and also by examining the larvæ, which, like those of insects, often show more clearly the true number of rings composing the body, because they are not soldered together so compactly as in the adult animal.

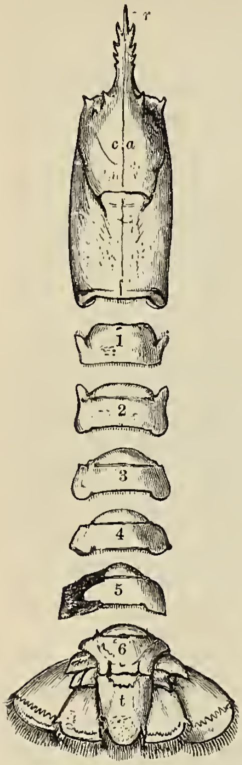


Fig. 1.—DIAGRAM OF THE BODY SEGMENTS OF A LOBSTER.

ca, the Carapace, covering both the seven cephalic and the seven thoracic segments; *r*, the Rostrum; 1—6, rings of the Abdomen; *t*, the seventh and last ring, also called the "telson," or tail spine. The plates on each side of the tail are the modified appendages belonging to the sixth segment.

Take a Lobster, and try to comprehend its armour-plated body in detail. It appears to be made up of two chief divisions, namely, a large head-shield (*ca*), having a strong *rostrum* (*r*) or prow in front, like a ship's bowsprit, and behind this seven distinct and movable rings or segments, the seventh and last united to the sixth, and marked *t* in the engraving (Fig. 1). Each of these body-rings, save the hindmost, which is called the *telson*, has one pair of appendages attached to it, those of the last but one being expanded to form a broad and powerful swimming tail. The head-shield, however, covers no fewer than fourteen pairs of appendages, so that there ought to be as many as fourteen rings in this division, all more or less soldered together, thus making, with the body, no fewer than twenty-one segments.

In fact, this is the number of body-rings most generally found among the various members of this class, and although instances occur among the extinct group of the *Trilobites* and the living forms of the order *Branchiopoda* (see table, p. 196), in which a greater number than twenty-one segments can be detected, and also among the higher *Decapoda* (Crabs and Lobsters), in which fewer than twenty-one segments are visible, yet the former must be treated as "exceptions which prove the rule," whilst in the latter it can be shown that in their young or larval stages they do possess the full number of twenty-one segments, but that in the adult animal some of these become permanently soldered together. It is found convenient to treat the first seven of these rings as forming the head (*cephale*), and the second seven as the *thorax*, or middle body, and the last seven as the abdomen. But in the Crab and Lobster the seven body-rings forming the *thorax* are entirely concealed beneath the great overarching carapace or head-shield, which is really composed of the rings of the front segments of the head enormously developed, so as to cover over all the others in the Crab, and all but the last seven abdominal rings in the Lobster. If, however, this roof-like head-shield be carefully removed, the thin walls of the seven thoracic body-rings are actually to be seen there, only they are concealed beneath the overarching head-shield, each ring giving attachment to one out of the seven pairs of jointed legs belonging to this division of the animal's body.

The first and most anterior pair of appendages in a Crustacean is composed of the two eye-stalks, each bearing an eye (Fig. 2, A) at its extremity. The *mouth*, which is placed in the centre of the head, just beneath the rostrum, has a small median plate in front, called the *labrum* (Fig. 2, B), or upper lip-plate, and a two-lobed piece behind it, called the *metastoma*, or lower lip (Fig. 2, C).

The second pair of appendages, following in order after the eyes, are called the antennules, or inner antennæ (Fig. 2, D), each consisting of a protopodite (or root-footlet) bearing two long, slender, many-jointed feelers, representing the two parts of an ordinary jointed limb, one being called the *exopodite* (or outer footlet), and the other the *endopodite* (or inner footlet). These undoubtedly serve as important organs of touch, and at the base of each in the protopodite is a small sac, opening externally by a narrow cleft guarded by hairs. At the bottom of this sac is a prominence wherein the auditory nerve terminates, and on which are very delicate hairs with silicious particles which have (apparently) found their way in from the exterior. The third pair of organs are the two great feelers or outer antennæ (Fig. 2, E), which exceed in length the entire body of the Lobster. Like the

antennules, they consist of a stout basal portion, to the side of which a large scale (the *exopodite*) is articulated, and from its extremity the long single many-jointed lash of the antenna takes its rise. At the base of each antenna is a green gland, which, according to Spence Bate, serves as an olfactory organ for conveying a sense of smell to the Lobster's nerves. The next six pairs of organs, which follow in succession after the eyes and antennæ, are all specially modified to serve the important business of nutrition, and generally to attend upon the mouth, that is, to hold, to cut, or to bite the food brought to it by the great claws. The first or innermost pair (called *mandibles*) is very strong, and toothed at the edge, and has a small palp or feeler (*p*) articulated to its upper border (Fig. 2, F); the edge forms a powerful crushing jaw, like a modified tooth. The next (Fig. 2, G) are called the *first maxillæ*. These are small and delicate organs fringed with hairs, and no doubt serve likewise as organs of touch, as do also, most probably, the *second maxillæ* (Fig. 2, H). This second pair have a large spoon-shaped "epipodite," or upper footlet, attached to the base (which serves a special office in connection with the gills), and is termed the "scaphognathite," or boat-like jaw.

Fig. 2.—APPENDAGES OF THE HEAD AND THORAX OF A LOBSTER.

I.—HEAD. 1. A.—The compound eyes fixed on their eye-stalks or *protopodites* (*pp*). [B.—The *labrum*, or upper lip, placed in front of the mouth.* C.—The *metastoma*, or lower lip, placed just behind the mouth.*] 2 D. One of the organs of touch: the *antennules*, or inner pair of antennæ; *i*, the seat of the auditory nerve. 3. E. One of the great outer pair of *antennæ*, or feelers. 4. F.—One of the *mandibles*, or crushing jaws; *en*, the *endopodite*; *p*, the point of attachment of the muscles of the jaw. 5. G. One of the first pair of *maxillæ*, or inner jaws. 6. H. One of the second or outer pair of *maxillæ*; *sc*, the part named the *scaphognathite*, or *boat*-like jaw. 7. I. One of the first pair of *maxillipedes*, or inner jaw-feet; *ex*, the *exopodite*; *en*, the *endopodite*; *ep*, the epipodite.
II.—THORAX. 1. J.—One of the second pair of maxillipedes, bearing a small gill or branchia on its basal joint. 2. K.—One of the third or outer pair of jaw-feet. This pair of appendages also bears each a gill or branchia attached to the basal joint or *protopodite*. [3. The next paired appendages which follow are the great chelate claws, or *pincers*, which are so largely developed in Lobsters. These are not drawn.] L.—One of the second pair of thoracic legs; *ep*, epipodite; *g*, gills or branchiæ; *en*, endopodite; *p*, the protopodite or first foot joint. M.—One of the last pair of thoracic legs; *p*, position of the opening of the *vas deferens* in the male.

The pair which follow (Fig. 2, I), named the *first maxillipedes*, or "jaw-feet," complete the jointed organs belonging to the head. They differ but little from the first pair of *maxillæ* (G), save that they bear a long and slender epipodite, or upper footlet, attached to the basal joint, the function of which (like that of the scaphognathite attached to H) is connected with the *branchiæ*, or gills, to be presently described. Here the seven thoracic appendages commence, and it may be noticed in the two succeeding pairs of jointed organs—although called "the second and third maxillipedes," or jaw-feet—that (Fig. 2, J, K) the inner footlet (*en*) attains considerable size, and, like that of the five following pairs of limbs, consists of seven joints. The third joint of the outer pair of maxillipedes (K) has a hard and sharply-toothed edge, and can be used either to cut its food or to hold it as in a vice. Both pairs of

* The *labrum* and the *metastoma* are not considered by carcinologists as paired appendages, but as parts of the mouth: they do not therefore represent body-rings.

maxillipedes have branchiæ attached to their bases. And now, in the succeeding five pairs of appendages, a marked change occurs, for these are undoubtedly legs, not jaw-feet. They vary at their extremities, the first three pairs being *chelate*, or clawed, at the end (Fig. 2, L), whilst the two last pairs have simple extremities (M). The first pair (not drawn in our woodcut) are those enormously large clawed nippers, so characteristic of the common Lobster, and which differ in form (like a dentist's forceps), one being very heavy and blunt-toothed, and the other more slender, and having its pincer more sharply serrated. The remaining four pairs of legs are of nearly equal size, and are true walking limbs. The seven pairs of thoracic appendages carry the breathing organs (*branchiæ*) upon their basal joints, or attached to the *pleuræ* or side-walls of the thoracic somites (body-rings). There are twenty of these structures on each side of the cephalothorax. They are pyramidal bodies, each consisting of a central ascending stem with numerous delicate horizontal branches through which the blood circulates. They are closely packed against the outside wall of each thoracic body-ring, and are protected from all liability to external injury by the overarching sides of the great carapace or head-shield. To aërate the blood thoroughly it is necessary that the water bathing the branchiæ should be incessantly renewed. This is brought about partly by the very movements of the legs, to the first joint of which they are nearly all attached, and partly by those long slender organs we have already noticed, attached to the basal joints of the maxillipedes and also to the legs, called *epipodites*, or upper footlets. These ascend between the gills, and serve not only to keep them apart from each other, but they also impart a slight degree of movement to them. The main agent, however, is the *scaphognathite*, or boat-like jaw, on each side (Fig. 2, H, *sc*), which continually spoons out the water from the gill-chamber in front, and thereby causes a fresh current to enter from behind.

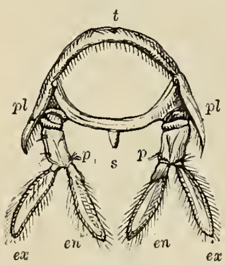


Fig. 3. — THE THIRD RING OF THE ABDOMEN OF THE LOBSTER.

t, the *tergum* (or back plate); *s*, the *sternum* (or pavement); *pl*, *pl*, the *pleuræ* (or side-ribs, called also "the epimeral pieces);" *p*,*p*, the *protopodites*, or first foot-joints, each bearing *ex* an *exopodite* or outer, and *en* an *endopodite*, or inner podite, or foot, or swimmeret.

The fourteen anterior segments which form the head and thorax in the Crab and Lobster being so constantly found blended together in one, are frequently termed the *cephalothorax*, a very convenient name for this compound structure. The seven body-rings which follow (called the *abdomen*) are seldom so much altered that one cannot at once see the separate joints or segments of which the body consists. In the Lobster, as seen by the woodcut (Fig. 1), all the seven rings can be readily examined separately, but in the Crab the abdomen is often quite small, almost rudimentary, and in one family (called the *Leucosiadæ*) the joints are soldered together into one piece, forming a small hollow enamelled lid to protect the eggs. In Fig. 3 is seen the third ring of the abdomen of the common Lobster, which may serve to represent the main characteristics of the second, third, fourth, and fifth body-segments. Each of these has two paired appendages attached to the underside or *sternum* (*s*) springing from one "root-footlet" (*p*), and giving rise to two swimmerets, fringed with hairs, representing the inner (*en*) and outer footlet (*ex*).

Fig. 4.—SIDE VIEW OF COMMON CRAB WITH ITS ABDOMEN EXTENDED AND CARRYING A MASS OF EGGS BENEATH. *e*, THE EGGS. (*After Morse.*)

In the sixth body-ring these swimmerets are greatly broadened out, and the outer footlet is divided into two by a transverse joint. These broad swimmerets, with the seventh or terminal somite (before spoken of as the "telson"), together form the expanded termination of the abdomen, which, by its forward projection through the water, drives the animal backwards. But the appendages belonging to the first abdominal ring in the Lobster have their swimmerets modified, in the males, into a pair of grooved processes, each like a small bent marrow spoon, and in the female into flexible soft processes.

The primary function of the abdomen in the Lobster, Prawn, and Shrimp, is undoubtedly that of

a powerful swimming organ, but in the Crab it is useless as an organ of natation, being quite rudimentary, especially in the males, but in the females of all these Crustaceans it serves as the nest for the eggs (or "berries," as the fishermen call them). When first extruded by the female, these eggs are coated with a viscid secretion, which thickens into threads, and causes the eggs to adhere to each other and to the fine hairs with which the swimmerets of the abdomen of the Lobster and of the female Crab are fringed, and, thus protected, they are carried about by the mother until hatched (Figs. 4, 5).

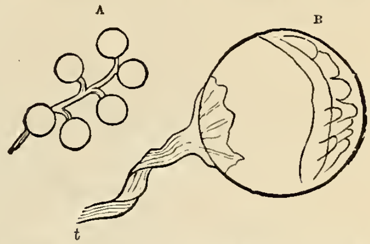


Fig. 5.—A, A FEW OF THE EGGS OF THE COMMON CRAB, ENLARGED. B, SINGLE EGG GREATLY ENLARGED, SHOWING MORE PLAINLY THE HARDENED THREAD (*t*) BY WHICH THEY ARE ATTACHED TO EACH OTHER. THIS EGG SHOWS THE YOUNG CRAB JUST BEGINNING TO FORM. (*After Morse.*)

If a longitudinal section (Fig. 6) were made through the hard and soft parts of a Lobster, it would be found that its nervous system occupies the ventral, or belly surface, of the animal's body, and consists of two parallel chords, so closely united, that, save near the stomach, where they separate to form "the œsophageal ring," they present only the appearance of a simple chord having a single ganglionic enlargement at each segment of the thorax and abdomen. But where the gullet passes to the stomach, the most anterior thoracic ganglion sends forward *two distinct* chords, which are united by a commissure or cross nerve behind the œsophagus, and have each a small ganglion on either side which gives off nerves to the mandibles, the stomach, the heart, the liver, and the intestines. These chords then unite once more in a single large ganglion in front of the mouth, and hence called the *supra-œsophageal* ganglion. This is *the Lobster's brain*, and its nerves go to the feelers, the eyes, and the other sensual organs of the animal. Above the nervous system is the alimentary canal, or the great duct or intestine by which the functions of digestion and nutrition are carried on.

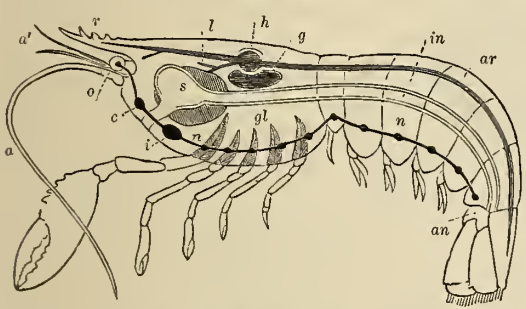


Fig. 6.—DIAGRAMMATIC SECTION OF A LOBSTER'S BODY.

a', the antennules; *a*, the antenna; *r*, the rostrum; *h*, the heart; *ar*, the artery; *gl*, the gills or branchiæ; *s*, the stomach; *l*, the liver; *g*, genital organs or ovaries; *in*, the intestine; *an*, anus; *n*, *n*, the nervous system with its several ganglia or nerve masses; *o*, the optic ganglion; *c*, the cephalic ganglion; *i*, œsophageal ganglion.

We have already seen with what an array of weapons, claws, foot-jaws, jaws, and mandibles, for cutting, crushing, tearing, biting, and generally pulling to pieces, a Lobster's mouth is armed; but, as if still further to insure perfect digestion, the stomach itself is provided with a set of calcareous teeth covered with strong ridges like the grinding surface of the tooth of a small Rodent or Kangaroo Rat. These gastric teeth (Fig. 7) triturate the food against a fixed calcareous ridge, also set in the wall of the stomach, and are moved by appropriate muscles. In the lower chamber of the stomach, leading to the intestine, and named the *pylorus*, a series of fine hairs are placed, which prevent the escape of the coarser particles of food, until they have been repeatedly subjected to the molar-like action of these gastric teeth. The liver in both the Crab and Lobster is a very large and highly complex organ, not solid like the human liver. The secreted fluid, or bile, is poured by two openings into the pylorus. Immediately beneath the cephalic shield of the Lobster lies the heart and the great main artery which supplies the entire length of the body. The heart consists of a single ventricle, which gives off six arteries by which the arterial blood is conveyed to the various organs of the body; it also receives by two main trunks the blood which has passed through the branchiæ. The arteries have valves at their openings, and after ramifying they end ultimately in capillaries, connected at last with what are called

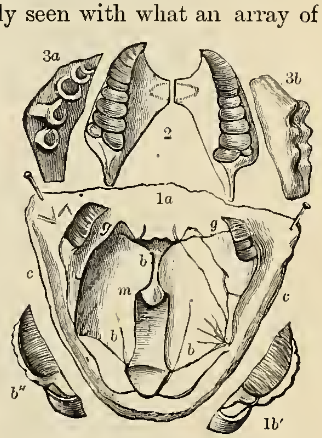


Fig. 7.—GASTRIC TEETH OF LOBSTER AND CRAB.

1*a*, stomach of Crab laid open; *b*, *b*, *b*, fixed calcareous plate against which the two gastric teeth, *g*, *g*, are opposed; 1*b'* and *b''*, the two grinding teeth enlarged; 2, gastric teeth of Lobster; 3*a*, 3*b*, fossil gastric teeth of *Dithyrocaris*, from carbouiferous limestone.

"venous sinuses." Here the blood is collected, and thence passes up into the gills to be oxygenated, after which it is returned to the heart.

With the exception of the CIRRIPEDIA (see p.196), the two sexes in the Crustacea are always distinct. Among many of the Crustacea, the antennæ and the great claws are specially developed in the male. This is the case in the claws of *Corystes* and *Macrophthalmus* and many others, whilst in *Cyclops* one of the antennæ in the male is specially modified for clasping the female. In the Crab the female lays eggs which have been already fecundated. In the Lobster the eggs are fecundated after their extrusion from the ovaries, whilst adhering to the abdomen of the female.

In nearly all the Crustacea the young undergo a series of metamorphoses after they quit the egg. This is especially the case with the truly marine forms. Among the DECAPODA (Crabs and Lobsters) some few species certainly quit the egg in the same form as their parents, with apparently the same number of jointed appendages to their bodies. This is the case with the River Cray-fish with several Land Crabs (*Gecarcinus*, &c.), with a species of *Dromia*, and with the common Garden Wood Louse (*Oniscus*, *Porcellio*, and *Armadillo*), which likewise nearly resemble their parents at birth.

One of the most interesting series of metamorphosis undergone by any of the Crustacea is that passed through by the young of the common Shore Crab (Fig. 8). In this species the metamorphosis is a perfectly gradual one, and dissimilar as is the zoea when it quits the egg from the adult animal, yet nevertheless the change at each moult is so small that it is only by a comparison between the earliest and the last stages that the amount of the change which has actually taken place can be fully appreciated. Thus, in the zooid state the young Crab has fixed eyes without eye-stalks, a long body, destitute of any appendages; it has no walking legs, but it is a free-swimming form, performing its locomotion with its maxillipedes, or jaw-feet (*m*), which are greatly developed, serving as a pair of long oars, the long hairs of which probably fulfilling the office of branchiæ. Even when by successive moults the true ten-footed character is seen, the young nevertheless present at first a greater likeness to the long-tailed Lobsters than to the short-tailed Crabs. These transient characters displayed by the larvæ are found to be persistent in many of the lower and simpler forms now living, and they also characterised some of the ancient fossil Crustacea found in the Silurian formation. Thus it may be seen that the stages of development of the individuals of to-day are but a reflection of the life-history of the class in past geological time.

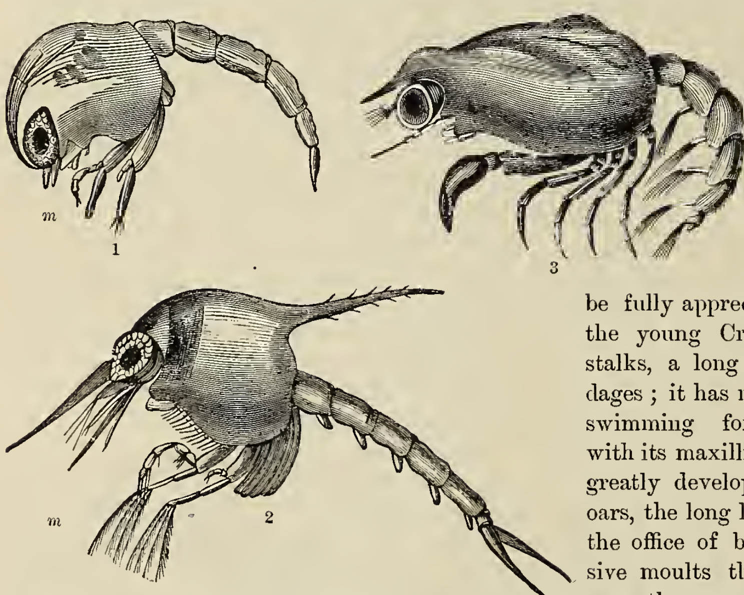


Fig. 8.—THREE STAGES IN THE METAMORPHOSIS OF THE COMMON SHORE CRAB. (*Carcinus mænas.*)

1, a newly hatched zoea; 2, a more advanced stage of same, 3, side view of still older larva (*Megalopa* stage). (*After C. Spence Bate.*)

Still more strange are the changes undergone by the brood of some Prawns of the genus *Penæus* observed by Fritz Müller (Fig. 9–1, 2, 3, 4, 5). These quit the egg with an unsegmented ovate body (2), a single eye in front, and three pairs of swimming feet, of which the first pair are simple, and the other two pairs branched. In this stage, called the *nauplius*, there is no trace of a carapace, the paired eyes are wanting, and also the masticating organs, the mouth being covered by a helmet-like hood. After several moults the *nauplius* becomes a *Zoea* (3), being furnished with maxillæ and two pairs of jaw-feet. The third stage of the same Prawn (4) exhibits still more remarkable changes, the paired eyes, the segments of the thorax, the rudiments of the feet are seen, all the appendages of the mouth and head can be counted, and the plates of the tail sprout forth. And now another great change takes

place, and the *zoea* passes into the *mysis* form (5); the antennæ cease to serve as organs of locomotion, their place being taken by the thoracic feet, which are furnished with long hairs or bristles. The

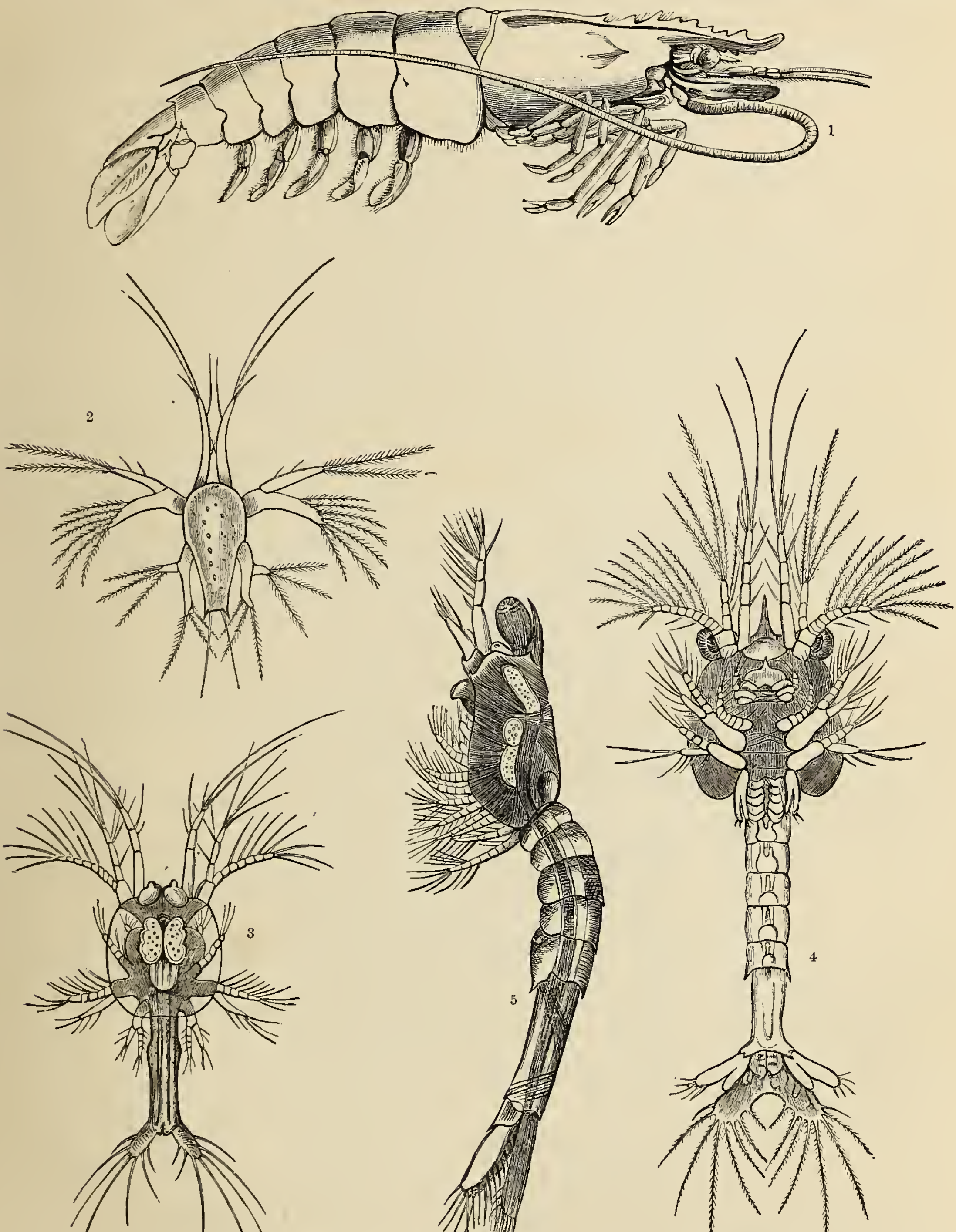


Fig. 9.—METAMORPHOSIS OF A PRAWN OF THE GENUS *Penæus*. (*After Fritz Müller.*)

1, adult, half natural size; 2, *nauplius* stage of young Prawn as it quits the egg; 3, *zoea* of same Prawn; 4, older *zoea* of same species; 5, *mysis*-form of ditto. (2, 3, 4, and 5, are all magnified forty-five diameters.)

abdomen is fully developed but has no appendages. Nothing can well be imagined more diverse than the *zoea*, *nauplius*, and adult stages in the life history of this Prawn.

Although the young of nearly all the Crustacea pass through numerous moults before attaining the adult state, yet, even after maturity, the shelly envelope is not permanently retained, but is exuviated and renewed as often as the growth of the animal necessitates its enlargement. By this wonderful provision the otherwise inelastic corselet is prevented from interfering with the continued growth of its wearer. The process of moulting is exactly analogous to the shedding of the skin and scales in reptiles. In *insects*—as all know who have kept silkworms—this moulting takes place several times in the *grub* or *larva* before it finally arrives at the perfect state. It then occurs no more. Insects, therefore, cannot grow after they reach the imago, and their life is consequently soon ended. Crabs, on the contrary, go on moulting and growing larger for many seasons, and each year they lay their eggs, so that they are more prolific, although less highly organised, than the insect tribe. The manner in which Crabs cast off their old shell is very singular, usually without producing any change in their external form, and when they have quitted the old habitation the whole body is already covered with a new suit of armour, which is, however, still soft, and does not acquire its requisite solidity for some hours, or even days after the operation.

The Crustacea also possess the power of reproducing injured or lost limbs; if one or more distant joints of a limb be torn off, the animal has the power of throwing off the remainder of the limb. This separation always takes place at the base of the first joint. The perfect restoration of the limb is not effected at once. After the first moult a new limb is produced of diminutive size. After a second, the new limb is very nearly twice as large as at the first, and at the third it advances nearly to its natural bulk and form. It is said that the noise of a thunderstorm or the discharge of a cannon will cause Crabs and Lobsters to throw off their claws; the same effect is also produced by the infliction of any sudden injury. The Broad-clawed Porcelain Crab (*Porcellana platycheles*), if seized by the claw, will leave it behind him and beat a retreat without it.

The accompanying table may serve to convey a general notion of the Crustacea as a class.

CLASS CRUSTACEA.

DIVISIONS.	LEGIONS.	ORDERS.
I.—THORACIPODA.—*Special* locomotory organs belonging to the *thorax*.	1. PODOPHTHALMIA.—Eyes on moveable foot-stalks. Branchiæ proper almost always present. Thorax covered more or less completely by cephalic shield.	1. DECAPODA. Five pairs of thoracic feet. *a*, BRACHYURA. (Short-tailed.)—Crabs.
		b, ANOMOURA. (Various-tailed.)—Hermit Crabs.
		c, MACROURA. (Large-tailed.)—Lobsters, Shrimps.
		2. STOMAPODA. (Mouth-footed.)—*Squilla*, *Mysis*, &c.
	2. EDRIOPHTHALMIA.—Eyes fixed. Branchiæ formed of modified appendages. Limbs usually seven pairs. No cephalothoracic carapace.	3. ISOPODA. (Equal-footed.)—Wood Lice, *Oniscus*, *Idotea*, &c.
		4. AMPHIPODA. (Both feet.)—Sand-hoppers, *Talitrus*, *Gammarus*.
II.—GNATHOPODA.—Limbs nearly always belonging to the *head*, but *not* generally *specialised*, as their bases perform the part of jaws. Branchiæ usually exposed and aiding in natation.	3. MEROSTOMATA.—The mouth furnished with mandibles and maxillæ, the terminations of which become walking or swimming feet.	5. XIPHOSURA. (Sword-tails.)—King Crabs, *Limulus*.
		6. (EURYPTERIDA. *Extinct.*)—*Eurypterus*, *Pterygotus*, &c.
	4. BRANCHIOPODA.—Most of the appendages, save those of the head and mouth, converted into lamelliform branchiæ.	7. (TRILOBITA. *Extinct.*)—Trilobites, *Calymene*, *Phacops*, &c.
		8. PHYLLOPODA. (Leaf-footed.)—*Apus*, *Branchipus*, &c.
		9. CLADOCERA. (Branched horns.)—Water Fleas, *Daphnia*, &c.
	5. LOPHYROPODA.—Locomotory organs having stiff hairs. Branchiæ attached to mouth organs.	10. OSTRACODA. (Shell-covered.)—*Cypris*, *Cardona*, &c.
		11. COPEPODA. (Oar-footed.)—*Cyclops*, *Diaptomus*, *Cetochilus*, &c.
III.—ANCHORACEPHALA.—Adult (female) attached by the head, and permanently fixed.	6. CIRRIPEDIA.—Adult animals permanently attached to some living or dead object. Sexes usually united.	12. RHIZOCEPHALA. (Root-headed.) Parasitic forms.—*Peltogaster*, *Sacculina*, &c.
		13. BALANIDÆ. (Acorn shells.)—*Balanus*, *Coronula*, &c.
		14. LEPADIDÆ. (Barnacles.)—*Lepas*, *Scalpellum*, *Pollicipes*, &c.

CHAPTER II.

CRUSTACEA (*continued*).—CRABS, LOBSTERS, AND SHRIMPS.

BRACHYURA, CRABS—Cephalisation—Sizes of various Crabs—The Spider Crabs—The Great Crab—The Common Shore and Harbour Crab—The Swimming Crabs—The Velvet Fiddler Crab—The Masked Crab—Land Crabs—The Pea Crab—ANOMOURA, HERMIT CRABS—Their Houses—The Land Hermits—The Robber Crab—MACROURA, LOBSTERS—The Common Spiny Lobster—The Common Lobster—The Norway Lobster—The Common River Crayfish—The Eye of Crustaceans—The Brown Shrimp—The Common Prawn—Blind Crayfish.

FIRST LEGION.—PODOPHTHALMIA.

ORDER DECAPODA.—BRACHYURA (CRABS).

THE Crab is certainly the highest representative of the Crustacean class, and in this ten-footed order are included some of the most active and intelligent members of the community, the Land Crabs and Shore Crabs, and also the largest representative of the class, the *Inachus Kempferi*, from Japan. Crabs furnish the best illustration among the Crustacea of that concentration of organs around a single nerve-centre, which has been aptly termed *cephalisation* (Fig. 10). Instead of a long body composed of a large number of rings, each having its own nerve-ganglion (Fig. 11), we have in the Crab one large cephalo-thoracic ganglion (T) representing nearly the entire nerve force of the body, the supraœsophageal ganglion (C) only giving rise to the nerves of sense and volition.

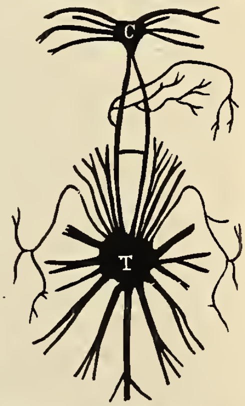


Fig. 10.—NERVES OF MAIA SQUINADO.

The highest concentrated type of Crustacean is exemplified by *Maia* and the Spider Crabs, but, as a matter of fact, the Triangular Crabs, of which *Maia* and *Inachus* are examples, do not embrace, by any means, the liveliest and most intelligent of the order. The carapace in these is narrow in front, and generally forms a prominent beak, beneath which the mouth is situated. Notwithstanding the length of their legs, their movements are generally sluggish. Many of these Crabs are quite coated over with nullipore aud corallines, while others cultivate green and red seaweeds upon their backs, and thus disguised like Indians stalking game, they can readily approach their more active prey, then by a sudden and unexpected snap they will seize upon and hold with extraordinary firmness the small fishes which incautiously venture too near their ambush.

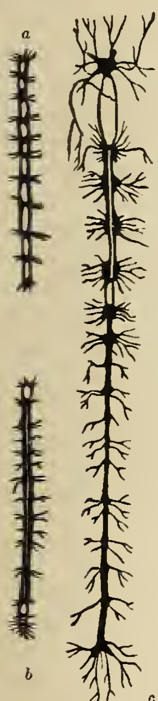


Fig. 11.—NERVES OF AMPHIPOD (*Talitrus*, *a*), ISOPOD (*Cymothoa*, *b*), AND LOBSTER (*Homarus*, *c*).

Although the British and European examples of *Stenorhynchus*, *Achæus*, *Pisa*, *Inachus*, *Arctopsis*, and *Hyas*, are all quite small forms of Crustacea, and even *Maia* is by no means a large Crab, yet in the British Museum there are specimens of the *Inachus Kempferi* from Japan which measure ten feet between the tips of the clawed fore limbs; the body (like that of other of the Triangular Crabs) is comparatively small and rather convex in shape: the claws are thin and about six feet in length. These monstrous Crabs are said to be eaten in Japan.

The Slender-beaked Spider Crab (*Stenorhynchus tenuirostris*) is one of the most curious of these triangular Crabs. When alive it is of a lovely pink and puce colour, the ova are of a light orange-brown. When seen sitting in a group of corallines of darker hue it presents a striking object in an aquarium. This species is frequently to be met with at Torquay in deep water. It is remarkable for the great length of its rostrum, which equals that of the entire carapace. Its small body and exceedingly long and slender limbs make this form the most spider-like of all the Spider Crabs (see Fig. 12).

The Four-horned Spider Crab (*Pisa tetraodon*) is a good illustration of one of the commonest of these small British Crustaceans. Like all the group, the carapace is triangular and elongated in front; the rostrum is large, strong, and prominent, and forms two strong horns. The margin of the carapace is also armed with spines, and the surface has numerous tubercles and hairs upon it. The abdomen of the female is very large and broad, and when laden with eggs exceedingly prominent. They are abundant at Bognor and other points along the south coast of England, and being attracted, like their larger brethren, by the smell of

stale fish, they frequently enter the Crab and Lobster-pots to the number of twenty to thirty, and so meet with an untimely end. They are usually so overgrown with corallines as to be almost indistinguishable.

The Spinous Spider Crab (*Maia squinado*) has a very convex and circular carapace, growing more triangular with age by the increased length of the rostral portion (Fig. 13). The centre of the carapace has a group of seven rounded and swollen prominences, and the whole surface is covered with minute spines and tubercles, with larger spines on the sides and front border. The rostrum has two strong and prominent diverging horns. The antennæ are small. The chelate fore legs are considerably longer and stouter in the adult male and much smaller in the young and in the adult females. There are few Crustacea in which age produces so great a change of form as in the Spider Crab. In the young state the fore legs are slenderer and shorter, and the front of the carapace is broader in proportion. *Maia* is common to the western and southern coasts of England, and is also found on the southern coast of Ireland. It is by far the largest species of the family, and, with the exception of the Great Crab (*Cancer pagurus*), it is the largest of the British Brachyura. The carapace of a specimen taken in Plymouth Sound measured eight inches in length and nearly six in breadth, whilst the length of the fore limbs was fifteen inches. It is eaten by the poorer classes, though it is but indifferent food. Like all the other triangular Crabs, the fishermen inveterately term it "spider," and they appear to have very little idea of any affinity between these forms aud the Crabs, properly so called. Some years since Professor Bell saw in one of the back streets of Poole, near the waterside, a little girl standing by a small table, on which was a plate containing two of these Crabs of moderate size, cooked and for sale. On being asked by the Professor, "Pray, do they eat these Crabs here?" she replied, with a look of great surprise at his ignorance, "They ben't Crabs, sir, them's *spiders!*"

Fig. 12.—THE SLENDER-BEAKED SPIDER CRAB. (*Stenorhynchus tenuirostris. Leach.*)

The Great Crab (*Cancer pagurus*) is one of the most familiar forms of all the Crustacea, because one meets with it on the stall of every fishmonger, and in this country it is largely consumed as an article of food, especially in all our great cities. Its chief feature is that the external antennæ have a very long and thick basal joint; the terminal portion, or feeler, is very short and slender. The great claws have black tips, and are equal in size, and of great strength and thickness. The carapace is nearly plain, with an oblong ovate outline much broader than long, the anterior border being marked by a row of ten square uniform teeth. The great claws and carapace are smooth, and the four simple walking legs are hairy.

This Crab was eaten in the time of the Romans, and has formed an article of diet probably ever since that period. Its excellence is mainly due to the enormous development of the liver, which occupies the two anterior sides of the carapace, and is deemed by most the "tit-bit." Its picture may be seen in one of the beautiful tessellated Roman pavements in the British Museum.

The fishery for these Crabs constitutes an important trade on many parts of the coast. The

number annually taken is immense, and as the occupation of procuring them is principally carried on by persons who are past the more laborious and dangerous pursuits of general fishing, it affords a means of subsistence to many a poor man who, from age or infirmity, would be unable without it to keep himself and his family from the workhouse. They are taken in what are termed "crab-pots," a sort of wicker trap, made by preference of the twigs of the golden willow (*Salix vitellina*), at least, in many parts of the coast, on account, as the fisher-folk say, of its great durability and toughness. These pots are formed on the principle of a common wire mouse-trap, but with the entrance at the top. They are baited with pieces of fish, generally of some otherwise useless kind; these are fixed into the pots by means of a skewer. The pots are sunk by stones attached to the bottom; and the situation where they are dropped is indicated, and the means of raising them provided, by a long line fixed to the creel, or pot, having a piece of cork attached to its free end. These pieces float the line, and at the same time serve to designate the owners of the different pots, one perhaps having three corks near together, towards the extremity of the line, and two distant ones; another may have one cork fastened crosswise; another two fastened together, and so on.

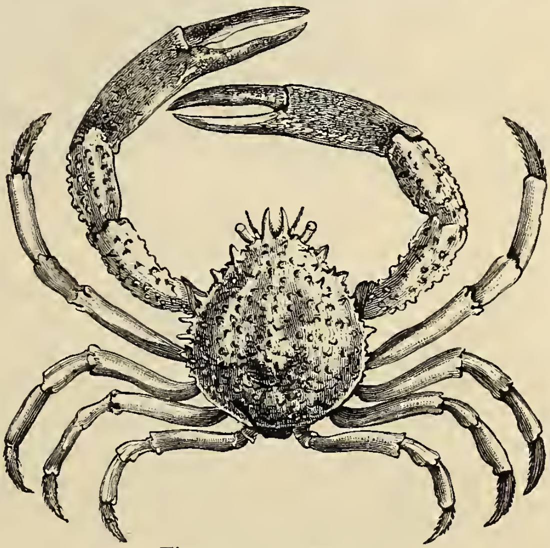


Fig. 13.—MAIA SQUINADO.

The Common Shore Crab (Fig. 14, *Carcinus mœnas*), so abundant in very shallow water around our coasts, and so industrious a scavenger between tide-marks, spends really much of its time almost out of water or on the edge of the advancing and the skirts of the receding tide. It is a true running Crab, yet its relations are all swimming Crabs, having their hind pair of feet specially modified for swimming, which is not the case in *Carcinus*. The front margin of the carapace is strongly toothed with five teeth on each side, and three lobes in front; the eyes are larger and certainly more useful "optics" than those of the great Crab. To any one who is a lover of an aquarium this very common Crab is an excellent and amusing species to keep and tame, for it soon loses all idea of shyness, and will "come to be fed" like any other pet, and take its food sharply. When very young these Shore Crabs moult frequently, and, being easily kept in small vessels of sea-water, one can all the more readily study their habits. One which was thus kept in confinement moulted on 11th April, 22nd May, the 3rd July, the 30th August, and 26th September of the same year, the acceleration of the last moult being attributed to the creature having been fed "like a prize beast," on purpose to try the effect on its growth. In casting its shell a Crab not only parts with every joint and plate of its many-jointed body, antennæ, foot-jaws, claws, and tail, but the very lining of its gills, of its stomach, of its eyes, and of other parts, is thrown off, and thus, when the creature has escaped, the shell seems as perfect nearly as the animal itself.

Pennant's Swimming Crab (*Portunus variegatus*) has a carapace which is rather longer than wide, and is toothed at its front border. Its fore legs are short, with exceedingly sharp claws (chelæ). The last pair of legs are flat and spatulate, and like an oar-blade, well adapted for swimming; the other three pairs of simple legs are fitted for running. They are common on the shores of the Firth of Forth and the Moray Firth, and in Ireland. Its colour is a dull purple-white mottled with a darker hue.

The Velvet Fiddler Crab (*Portunus puber*) has its front border armed with at least ten spines, and its entire carapace densely covered with hairs. The chelæ, or claws, and also the four pairs of simple legs, are thickly coated with a dense pile of fur. All the limbs have raised longitudinal lines or ridges upon their joints. The general colour of the Velvet Fiddler Crab is brown, but the longitudinal ridges on the legs are blue. This Crab is not uncommon on the south-west coast of England

and on the Irish coast. It is also met with in the Moray Firth, the Firth of Clyde, and in the Channel Islands, where it is known as the Lady Crab, from its velvet coat.

"An old male of the Velvet Fiddler is a striking and handsome Crab. His body generally is clothed with a short velvety pile of a pale brown or drab hue, from beneath which here and there shines out the glossy deep black shell, especially where rubbed, as at the edges. The feet, particularly the plates of the oars, are conspicuously striped with black, the large and formidable claws are marked with bright scarlet and azure, as are also the foot-jaws and face, while the eyes are of the richest vermilion, projecting from hollow black sockets." This species, when apprehensive of assault, uses its powerful claws "to strike transversely, as a mower uses his scythe."

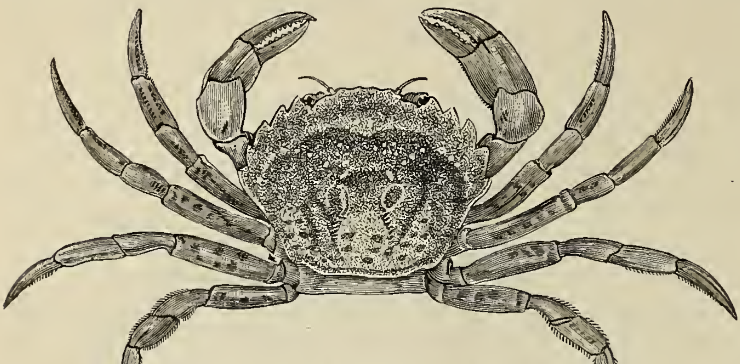


Fig. 14.—THE COMMON SHORE CRAB. (*Carcinus Mænas.*)

Henslow's Swimming Crab (*Polybius Henslowii*), the only known species of the genus (Fig. 15), exhibits the natatory structure to the greatest extent of any British species. The carapace even in the female is remarkably flat, and its form is nearly orbicular. The edge of the carapace has five teeth on each side. The eyes are keen and active; the chelæ are exceedingly sharp-edged. The four following pairs of limbs are all adapted for swimming. The colour is of a rich reddish-brown. The texture of the whole shell is far lighter in density than any of our coast species which live inshore. This is, in fact, a truly pelagic or open-sea Crustacean. The writer has seen this Crab in large numbers swimming on the surface of the Bay of Biscay one hundred miles from land; and far off the coast of Cornwall the fishermen take them in the act of eating the Mackerel, which they pursue and fasten on with their knife-like nippers, until the terrified fish becomes exhausted and is speedily vanquished and devoured.

Another and much larger species of Swimming Crab than our own, named *Portunus pelagicus,* occurs in the seas of China and Japan, and extends as far south as the Gulf of Carpentaria. It preys upon quite large fishes, and is "built," as shippers would say, "for speed and lightness." Its habits were well known to the Japanese, who have depicted this Crab most accurately in one of their many wonderful picture-books, printed from wood blocks, preserved in the British Museum. The *Portunus* is represented in the very act of catching a live fish many times larger than itself. These predaceous Swimming Crabs are much disliked by the fishermen, because, when they are taken in the nets with a haul of fish, they bite and mutilate all within their reach, as does the Dog-fish and the other small Sharks common along our coast.

Fig. 15.—HENSLOW'S SWIMMING CRAB. (*Polybius Henslowii.*)

Corystes Cassivelaunus (Fig. 16). In this singular Crab the carapace is longer than it is broad. The surface of the carapace is convex, and the regions somewhat distinctly marked by a groove surrounding the heart, the intestinal and genital regions, forming altogether a remarkable resemblance to the features of the human face, from which circumstance it has obtained the name of "the Masked Crab." The sexes of this Crab differ so much in appearance that they have been described as separate species. It is frequently to be obtained on the south and west coast of England and Wales. The habit of this Crab is to lie buried in sand with only the antennæ visible above the surface. This is a very ancient type of Crustacean; many representatives of it (*Palæocorystes*) occur fossil in the Cretaceous beds (Gault and Greensand) of this country.

As we have already pointed out, the branchiæ or gills are enclosed between the side walls of the thorax and the over-spreading head-shield (the "Crab-cart" of peasants' children in the English Eastern Counties), and are borne upon the basal joints of the thoracic limbs. As rapidity of movement necessitates increased activity in the circulation of the vital fluid in the body, we thus find that by this simple arrangement the branchiæ are brought directly into connection with the appendages specially engaged in locomotion. In a precisely similar manner we observe that the pectoral muscles in the bird, by their rapid action, accelerate their respiratory functions, consequently those birds whose flight is swiftest, such as the Swallows, naturally breathe most quickly. Amongst the Land and Shore Crabs, such as the *Grapsidæ*, the *Ocypodidæ*, the *Gecarcinidæ*, we find some of the most rapidly moving terrestrial forms of Crustacea. Respiration in these Crabs is, however, carried on essentially upon the same plan as in the aquatic species, that is, by means of *moistened branchiæ* or gills, not by pulmonary sacs, as in the Arachnida, nor by tracheæ, as in insects proper. Nevertheless, the aëration of the blood in the branchiæ of Land Crabs is so much more complete than it is among the aquatic species, that the Land Crabs are easily drowned by continued immersion in water.

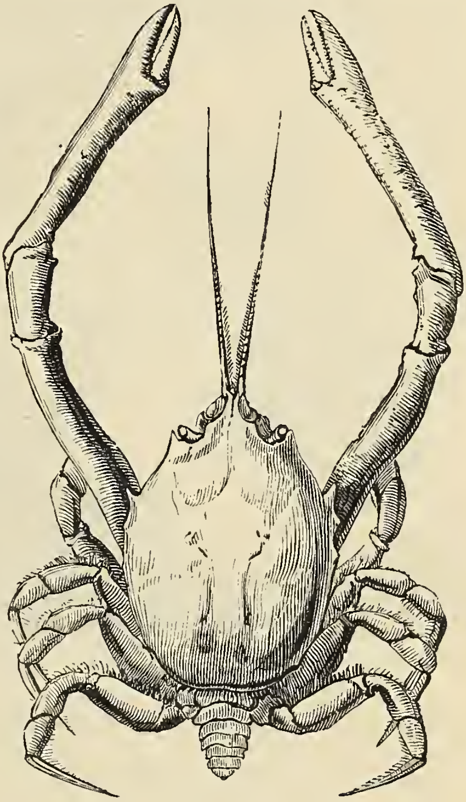


Fig. 16.—THE MASKED CRAB. MALE.
(*Corystes cassivelaunus.*)

Land Crabs are met with in the tropics in vast numbers. Of these, the most common and best known to us is the *Gecarcinus ruricola*, or "Countryman Crab," once so abundant in the highlands of Jamaica, and still so formidable in Montserrat and other of the West Indian sugar-producing Islands (Fig. 17). When the season for spawning arrives vast armies of them set out from the hills, and, undaunted by opposition, march in a direct line towards the sea-shore for the purpose of depositing their eggs. Having reached the destined limit of their journey, they deposit their eggs below high-water mark in the sand, and re-commence their toilsome march towards their upland retreats. On their seaward journey they are in full vigour and fine condition, and this is the time when they are caught in great numbers for the table. Their flesh, which is of the purest whiteness, is highly esteemed, but, like that of all Crustaceous animals, is rather difficult of digestion. On returning from the coast they are exhausted, poor, and no longer fit for use. They then retire to their burrows, where they exuviate or shed their shells, a short time after which operation, and while in their soft state, they are considered by black connoisseurs to be a great delicacy. These Crabs, which take up their abode in the vicinity of sugar-cane fields, are very injurious to the planter, some of the species being particularly fond of the cane, the juice of which they suck and chiefly subsist upon. They also attack and destroy the growing shoots of the young plants.

Cardisoma carnifex, which usually inhabits the mangrove swamps of the West Indian Islands, lives principally upon the fruit of a species of *Annona*, which grows in those places. But nothing comes amiss to it. Those individuals whose residence is in the neighbourhood of the cemeteries are said to burrow down to get at the dead bodies, and Dr. Duchassaing tells us that the West Indian burial grounds are pierced in every direction by burrows of these animals. Nevertheless, the *Cardisoma* is regarded as a luxurious article of food by West Indians, who, however, take care only to eat those which are obtained in the mangrove swamps, as far as possible from the cemeteries. They are caught in box-traps baited with a piece of their favourite fruit, and after their capture they are usually kept some time, and fattened with broken victuals.

Land Crabs are very abundant in the Deccan; they have been found on the table-lands at an elevation of nearly 4,000 feet. But as they do not perform an annual migration to the sea for the purpose of depositing their eggs, it seems highly probable that the Deccan species frequents the margins of streams, and deposits its eggs in fresh water, in which case the nearest river would serve the same purpose; for the young must undergo their metamorphosis either in the water or within the egg itself before it is hatched, several authentic instances of which are known. Another form, the Calling Crab (*Gelasimus*), is a great burrower, inhabiting the coasts of Brazil, &c. He has one large hand and a small one, and from the way in which he is compelled to run in order not to overbalance himself with his big claw raised above his head, as if beckoning, he has obtained the name of Calling Crab. This powerful hand is used in throwing the earth and sand out of its burrow when digging, which he does most vigorously to a distance of a foot or more from the hole.

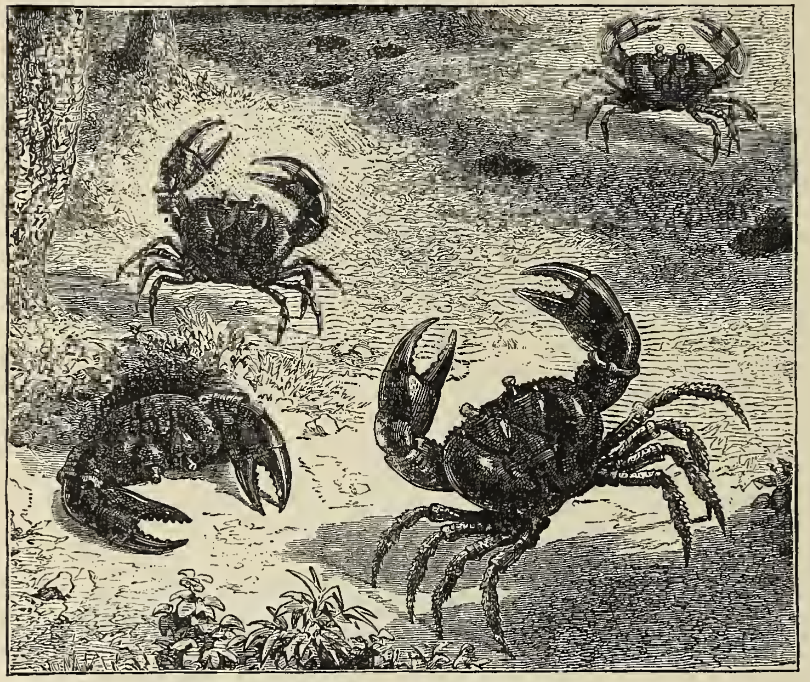


Fig. 17.—VIOLET LAND CRAB OF JAMAICA. (*Gecarcinus ruricola.*)

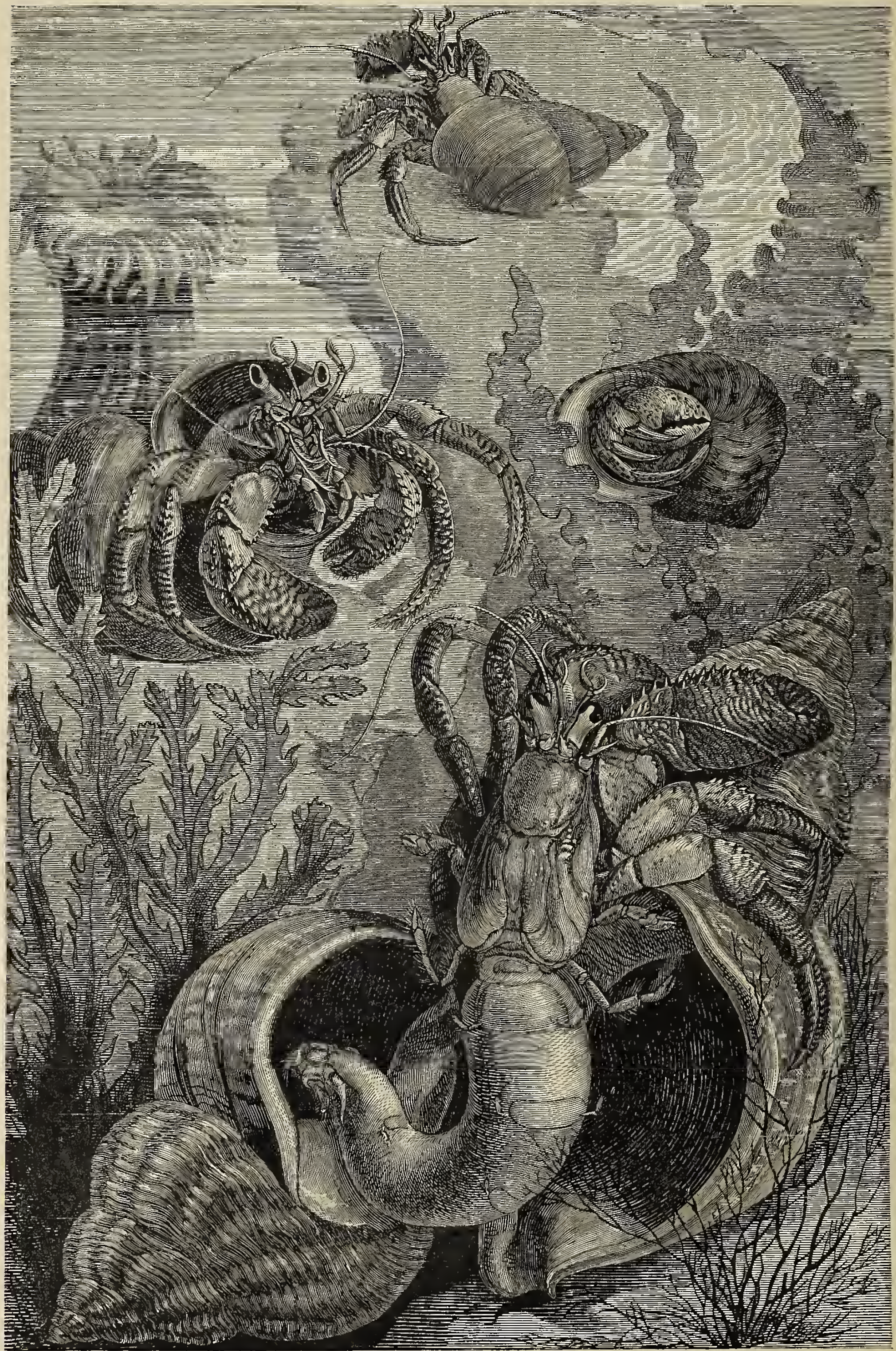
The *Ocypoda*, or Horseman Crab, from Rio, is another interesting species of Land Crab. It makes a loud grating sound by means of a series of small ridges on the inner surface of the hand against the prominent edge of the second joint of the same pair of legs. There is really no voice organ (truly so called) in any of the Invertebrata. Mosquitoes "sing," Bees "hum," Crickets "chirp," and Beetles "drone;" but these are all mechanical noises, made by movements of wings or legs, not with such a contrivance as the human throat. Most of these sounds are produced by an arrangement similar to that of the fiddle-bow drawn across the strings of the fiddle, whilst many of the harsher sounds have been aptly compared to the noise produced by street-boys scraping a stick along a row of iron railings.

The Pea Crab (*Pinnotheres*) is an interesting genus, both on account of its diminutive size and from its singular practice of making its habitation within the valves of living bivalve shells. The writer has taken numbers of them alive from shells as small as *Astarte* and *Cytherea* at Malaga. One species (*Pinnotheres pisum*, Fig. 18) is so common on the Irish coast, that Mr. W. Thompson obtained fourteen of them, by opening eighteen of the larger or Horse Mussel, dredged off the shore of County Down; and in the common Cockle at Youghal Mr. Ball found them so abundantly, that about nine out of every ten Cockles contained a Crab. Two and even three Crabs are occasionally found in one Mussel, or in one *Pinna*.

Fig. 18.—PINNOTHERES PISUM.

Pinnotheres veterum is the species found in the Mediterranean, and whose history, mingled with much fable, is recorded by some ancient authors.

The ANOMOURA, or irregular-tailed Crabs, form the connecting link between the Crabs and Lobsters, for, besides the Hermit Crabs proper, which are generally considered typical of the



A GROUP OF HERMIT CRABS.

1, Hermit Crab in *Achatina* shell; 2, Hermit Crab in Turbo shell; 3, Hermit Crab with Sea Anemone attached to its shell; 4, Hermit Crab in the act of shifting from one Whelk-shell to another.

Anomourous type, there are many forms which, save for the abortive character of the posterior pair of thoracic limbs, and their modified jaw-feet, might be placed with true Crabs or true Lobsters—*Dromia* with the former, and *Galathea* and *Munida* with the latter. Others again, like *Lithodes*, have the plates of the abdomen irregular or partly membranous, whilst in the true *Paguri* they are entirely unprotected by hard shelly plates. In the East and West Indies, and in the tropics generally, there are many species of *Anomoura* which live wholly or partially away from the sea, adopting terrestrial habits of life, and even becoming great climbers. They are met with living in forests often miles from the sea, and if land shells are not to be found, one species of Hermit Crab (*Cenobita brunnea*) protects its soft tail with an empty nut-shell, in which it makes itself perfectly at home.

The *Cenobita diogenes* (Fig. 20) is found on bushes a few hundred yards only from the sea living in empty land shells. It is abundant in all the West Indian Islands, and has been more than once brought over to this country alive with cargoes of guano. The writer kept one for some weeks in a fern-case in his study. It was housed in an *Achatina* shell, and no doubt it might have continued to live to this day, but it could not be induced to eat, and it was exceedingly difficult to discover what its proper food should be. This little Crab was a splendid climber, and its feats of agility were often surprising. It burrowed under stones, and seemed fearful of being looked at.

Charles Darwin says, "In every part of Keeling Island one meets with Hermit Crabs of more than one species, carrying on their backs the houses they have stolen from the neighbouring beach. The large claws or pincers of some of these Crabs are most beautifully adapted, when drawn back, to form an *operculum* to the shell, which is nearly as perfect as the proper one that belonged to the original molluscous animal. Certain kinds of these Hermits always select certain old shells only to live in."

The most remarkable of the Land Hermits is the *Birgus latro*, or Robber Crab (Fig. 19). Darwin says, "Keeling Island has no quadruped excepting the pig, and no vegetable in quantity excepting the cocoa-nut. On it the pigs, which are loaded with fat, almost entirely subsist, as likewise do the poultry and ducks. Even a huge Land Crab is furnished by nature with a curious instinct and form of legs to open and feed upon this same fruit. It is very common on all parts of the dry land, and grows to a monstrous size. It is closely allied or identical with *Birgus latro*. This Crab has its front pair of legs terminated by very strong and heavy pincers, and the last pair by others which are narrow and weak. It would at first be thought quite impossible for a Crab to open a strong cocoa-nut covered with the husk, but Mr. Leisk, one of the two British residents, assures me he has repeatedly seen the operation effected. The Crab begins by tearing the husk, fibre by fibre, and always from that end under which the three eye-holes are situated. When this is completed, the Crab commences hammering with its heavy claws on one of these eye-holes till an opening is made; then, turning round its body, by the aid of its posterior pair of narrow pincers it extracts the white albuminous substance. I think this is as curious a case of instinct as ever I heard of, and likewise of adaptation in structure between two objects apparently so remote from each other in the scheme of nature as a Crab and a cocoa-nut tree."

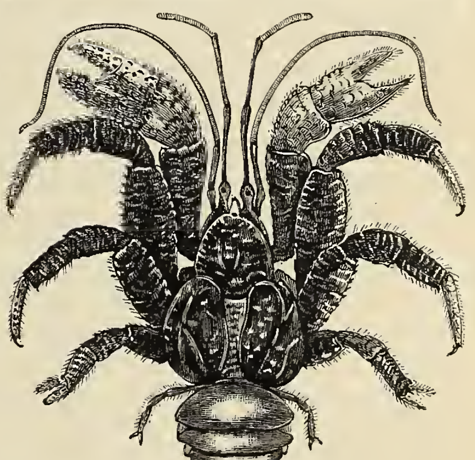


Fig. 19.—BIRGUS LATRO.

"The *Birgus* is diurnal in its habits, but every night it is said to pay a visit to the sea, no doubt for the purpose of moistening its branchiæ. The young are likewise hatched, and live for some time on the sea coast. These Crabs inhabit deep burrows, which they excavate beneath the roots of the cocoa-nut trees, and here they accumulate surprising quantities of the picked fibres of the cocoa-nut husk, on which they rest as on a bed. The Malays sometimes take advantage of their labour by collecting the coarse fibrous substance and using it as junk. These Crabs are very good to eat,

moreover, under the tail of the larger ones there is a great mass of fat, which, when melted, sometimes yields as much as a quart of limpid oil. It has been stated by some that *Birgus latro* crawls up the cocoa-nut trees for the purpose of stealing the fruit. I very much doubt the possibility of this, but with the *Pandanus* * the task would be very much easier. I understood from Mr. Leisk that on these islands the *Birgus latro* lives only on the nuts which fall to the ground." (C. Darwin: "A Naturalist's Voyage Round the World.")

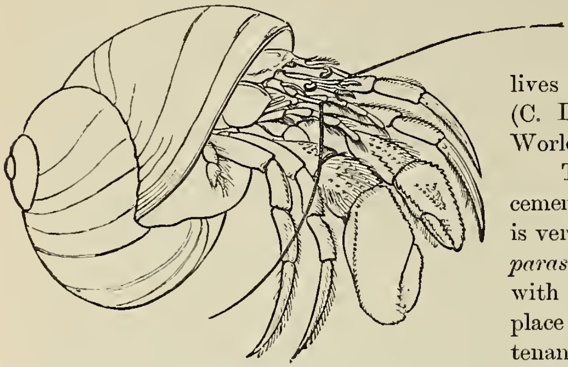


Fig. 20.—HERMIT CRAB (*Cenobita*) IN SHELL.
(*After Morse.*)

The friendship — interested or otherwise — cemented between Soldier Crabs and Sea Anemones is very remarkable. One Sea Anemone, the *Sagartia parasitica*, seems to be on very friendly terms with the Hermit Crabs, always selecting for its place of attachment the dead shell of some whelk tenanted by one. The Crab who sustains the honourable office of porter to this Anemone is invariably the *Pagurus bernhardus*.

Prof. Dana mentions another *Actinia* from the China Seas—the *Cancrisocia expansa*—which associates with *Dorippe* (an anomourous Crab), who holds the *Actinia* on its back with its two posterior pairs of legs.

DECAPODA—MACROURA. (LOBSTERS.)

The Macrourous (or large-tailed) type of the order (DECAPODA) is represented by the Lobster, essentially an aquatic form, and possessed of great powers of locomotion. The hinder segments of the body (termed the abdomen) are very much developed, and of nearly equal growth, being also compressed at the sides, so as to be somewhat cylindrical in form. They present a well-marked difference from the tail of the Crab (BRACHYURA), in which the segments are short and flattened, and expanded laterally. The abdomen in the Lobster is also terminated by a broad swimming tail.

The members of this division are very abundant numerically in both marine and fresh water.†

The Common Spiny Lobster (*Palinurus vulgaris*) has thick, extremely long, and stiff external antennæ, the basal joints of which are very large, and unite to form the front of the mouth. The three following joints are large, thick, and spinose. Each antennule has three very long and slender cylindrical basal joints with two small feelers at its tip. The outer jaw-feet are formed like feet. The true walking legs are all one-toed at their extremity. The first pair, however, which are thicker and shorter than the others, has a spine on the border of the last joint but one against which the last joint shuts, thus forming a rudimentary chela or nipper. The carapace is extremely rugose, being covered with spines and tubercles. The body segments are large, and the tail-fins well developed for swimming. The family of the *Palinuridæ* are of very ancient origin, going back in geological time to the Solenhofen rocks (Oolitic age). Only one genus now survives.

The genus *Palinurus* comprises several large edible species, one of which, the Common Spiny Lobster (*P. vulgaris*), inhabits our western coasts, and is brought thence in large quantities to the London markets. They are found chiefly on rocky coasts, and are often taken in the crab-pots. Great numbers of this Lobster are also eaten in France. Its flesh is much esteemed, though by some considered inferior in flavour to that of the Common Lobster (*Homarus vulgaris*). It reaches about a foot in length, and sometimes as much as eighteen inches. The antennæ are very long, just twice the length of the entire body. The carapace is thickly covered with spines of various sizes, and all the species have a large spine over each eye.

* *Proceedings of the Zoological Society*, 1832, p. 17.

† In his book on the Crayfish, Prof. Huxley mentions, that, in Tasmania, the genus *Engæus* (one of the *Parastacidæ*), a small kind of Crayfish, lives habitually on land in burrows, which they excavate in the soil (p. 306) and *Parastacus pilimanus*, from Santa Cruz, in the upper basin of the Rio Pardo, an affluent of the Jacuhy, was obtained "by digging it out of holes in the ground" (p. 308). So that the Crayfish is an exception to the general rule, that all the Macroura are trul-aquatic in their habits, and that none are terrestrial.

THE SPINY LOBSTER (*Palinurus vulgaris*).
[Female, bearing eggs attached to the false abdominal swimming-feet.]

The *Palinuri* live on mollusca and on other marine animals. They have the power of producing a very loud noise, by rubbing the first joint of their exterior antennæ against the projecting border of the carapace, or head-shield. Aristotle, Athenæus, and Pliny were acquainted with the animals of this genus, which they named *Locusta;* and the Greeks and Romans both used them as food.

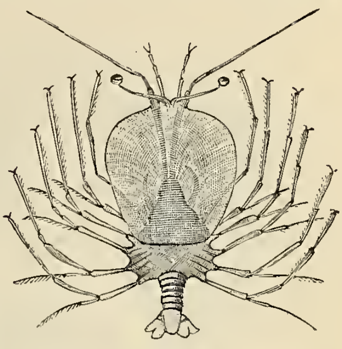


Fig. 21.—LARVA OF PALINURUS VULGARIS.

The development of the *Palinuridæ* seems to be very peculiar (Fig. 21). Claus observed in the ova of the Spiny Lobster (*Palinurus*) embryos with a completely segmented body, but wanting the appendages of the tail, abdomen, and last two segments of the middle body or thorax. They possess a single median and considerably compound eye; the inner antennæ are simple, and the outer are furnished with a small secondary branch; the jaws have no palpi or feelers. The jaw-feet of the third pair, like the two following pairs of feet, are divided into two branches of nearly equal length, whilst the last of the existing pairs of maxillipedes bear only an inconsiderable secondary branch. Coste is said to have bred the curious form of larva named *Phyllosoma* from the ova of *Palinurus*.

The Common Lobster (*Homarus vulgaris* Fig. 22,) prefers a rocky coast, and being somewhat of an epicure in his tastes, is tempted to such good purpose by the fishermen that as many as 25,000 live Lobsters are often delivered at Billingsgate in one day. If only as many are eaten in the whole of England as in London, this would be at the rate of 50,000 per day, or 18,250,000 annually. From March to August is the period of the greatest catch. Lobsters are sent alive packed in damp moss or heather from the south coast and Channel Islands, from Stornoway in the Island of Lewes, from

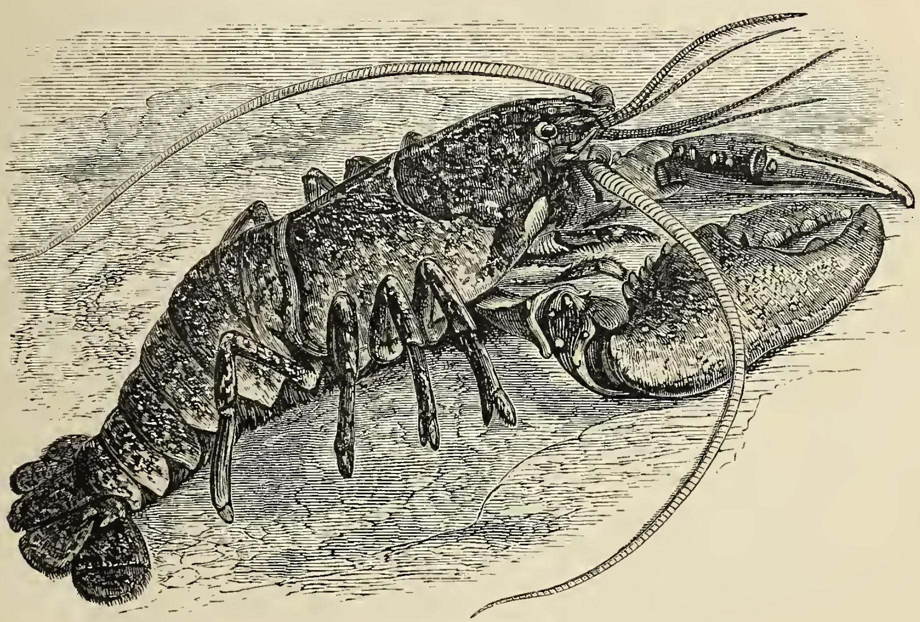


Fig. 22.—THE COMMON LOBSTER (*Homarus vulgaris*).

Ireland, Scotland, and the Orkneys. From Norway as many as 600,000 are received annually. Fishermen and salesmen are said to know the South Coast (English), Cornish, Scotch, Irish, or Norwegian Lobsters at sight, just as a cattle salesman knows a Hereford or Devon, a Scotch or Irish beast. The common Lobster weighs from eight to twelve pounds, but the great Lobster of the American coast (so largely imported in tins into England) weighs more than twice as much.

All the marine Macroura, or Sea Lobsters, undergo metamorphosis more or less considerable. Perhaps the changes passed through by the common Lobster present a less extraordinary variation

from the adult than in others of the long-tailed Crustacea. They are, however, sufficiently important to mention (Fig. 23). The eyes of the young Lobster are sessile, not mounted upon eye-stalks. The long antennæ are not seen, nor the beak or rostrum. The thoracic feet are rudimentary. The abdominal feet are entirely absent, as in the young Crab. At a later moult the jointed thoracic limbs are seen, and the antennæ begin to be developed. The hind body, or abdomen, is, however, still without appendages, and the eyes without eye-stalks. Still later these abdominal feet make their appearance.

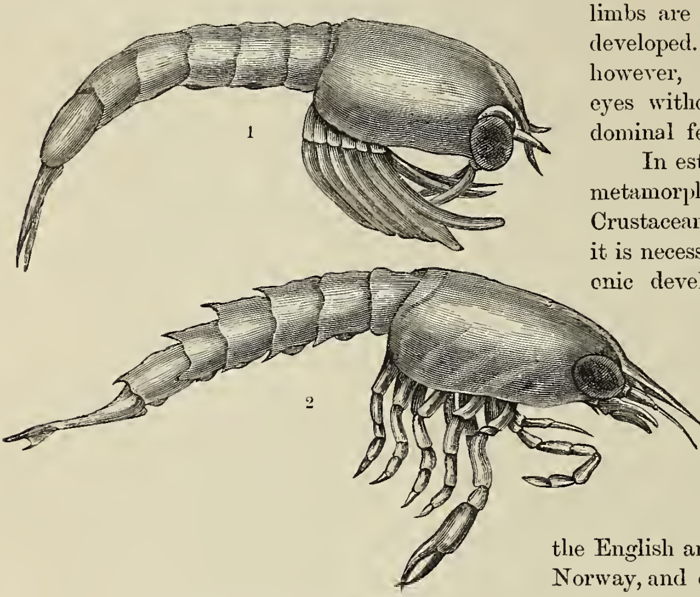


Fig. 23.—YOUNG LOBSTERS.
1, zoea just born; 2, after first moult.

In estimating the greater or less extent of metamorphosis undergone by the young of any Crustacean in its passage to the adult animal, it is necessary also to take account of its embryonic development, for many species, both of the *Podothphalmia* (or stalked-eyed) and *Edriophthalmia* (or sessile-eyed) Crustacea undergo these larval changes in the egg, whilst others (as *Asellus* and *Mysis*) do so in the incubatory pouch of the mother.

The Norway Lobster (*Nephrops norvegicus*, Fig. 24) occurs on both the English and French coast, as well as on that of Norway, and extends as far south as the Mediterranean. The body of this elegant species is long, and the segments extremely cylindrical in form; the cephalothorax is compressed at the sides. The great claws are long, slender, spiny, and ridged strongly down the centre; the rostrum is long and slender. The scale at the outer base of the antennæ is large. The eyes are large and prominent. The colour of this Lobster is much paler than that of *Homarus*, and there are bands of darker colour on the body-rings. There is only one species known.

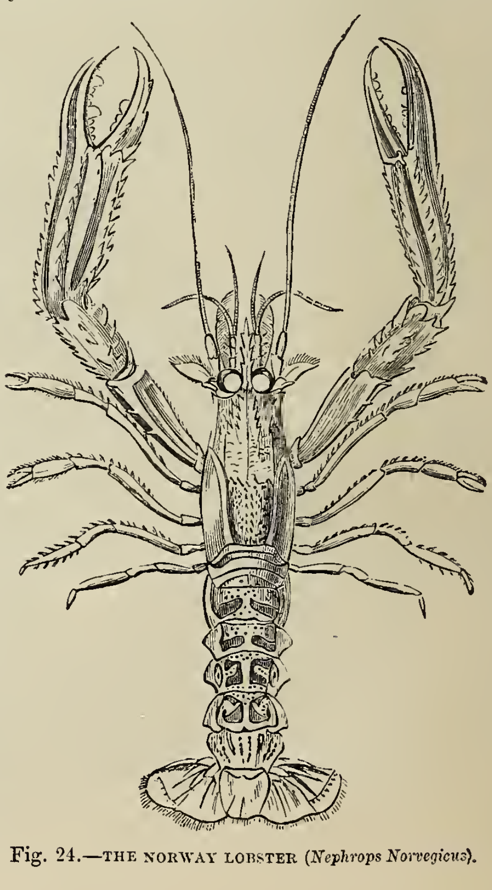


Fig. 24.—THE NORWAY LOBSTER (*Nephrops Norvegicus*).

The Common River Cray-fish (*Astacus fluviatilis*), a fresh-water genus, was separated by Milne-Edwards from the Lobsters, and may be readily known from others by the rostrum or beak having a small tooth on each side. Its carapace is granulated, and the *telson*, or median plate of the tail, is divided half-way up by a transverse joint across it, as are also the outer side-lobes of the tail. The outer antennæ have the second and third joints roundish, and covered by a broad and movable scale, which is narrowed towards each extremity, and pointed. The last joint or ring of the thorax is movable, whereas in the common Lobster the last thoracic ring is firmly adherent to the rest. The exopodite of the antennæ is reduced to a mere scale. All the abdominal appendages are well developed in both sexes, and in the males the two anterior pairs are somewhat like those of the male of *Homarus*, but less modified.

According to Huxley, the principal difference is to be observed in the gills, of which there are twenty on each side, sixteen belonging to the limbs and four fully-developed gills attached to the side of the thorax. Six of the former he calls *podobranchiæ*, or foot-gills, because they are attached to the *protopodite*, or first foot-joint, the other ten *arthrobranchiæ*, or joint-branchiæ, because their origin is on the joint of the leg where it unites with the thorax; lastly, the four on the sides are called by him *pleurobranchiæ*, because they spring from the part of the thoracic somite or body-ring known as the *pleuron*, or side piece, or *epimeral* portion of the segment.

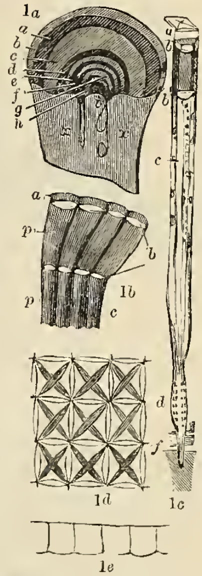


Fig. 25.—STRUCTURE OF EYE OF LOBSTER.

1a, section of eye, showing the several layers (a—h) composing it; 1b, 4 lenses of the eye, greatly magnified; 1c, a single lens, from the cornea to the optic ganglion; 1d, part of the surface of the eye; and 1e, section of same.

Our River Cray-fish (*Potamobius astacus*) is largely caught, and when fresh boiled is a dish not to be despised. It is largely imported into London for garnishing dishes with. The writer has with a friend taken over 900 River Cray-fish in the Thames and Severn Canal in Gloucestershire in a single evening between eight and twelve, with a series of simple scale-like nets, baited with liver.

The Cray-fish is one of those forms which is peculiarly interesting to the zoologist, as, according to the experiments of Ratke, it passes through its earlier metamorphosis in the egg, a circumstance which led Prof. Westwood in 1835 to doubt the correctness of Vaughan Thompson's discoveries as to the series of changes which the young of most species of Crustacea undergo after they quit the egg.

The most remarkable thing with regard to the genus is that, notwithstanding its inability to survive in salt or even brackish water conditions, its geographical distribution is wider than that of any other living Crustacean. Thus we find that representative species of our *Astacus fluviatilis* (which it seems, according to Huxley and others, we shall have in future to call *Astacus torrentium*) exist over the whole of Europe, save Sweden and Norway and Scotland, and that four other species inhabit the rivers which drain into the Caspian and the Black Sea. Two others belong to Japan and to the basin of the Amur, which sheds its water into the Pacific. The *Astaci* occur again in the rivers of North America west of the Rocky Mountains flowing into the Pacific, and the *Cambari* on the eastern or Atlantic side. It is more wonderful still that, separated by a wide equatorial belt, *Parastacidæ*, or representative forms, occur in the Southern Hemisphere, in New Zealand, Australia, Madagascar, and South America. The biggest of the Cray-fishes which attains a length of more than fifteen inches, being as large as a full-sized Lobster, belongs to the Murray River, South Australia. The strangest is the genus *Engæus* of Tasmania and the *Cambarus* of the United States, and *Parastacus pilimanus* from Brazil, which live habitually on land in burrows which they excavate in the soil. This is the only family of Macroura known to me which quits the water for dry land. Its geological history is as long as its geographical distribution is wide, for its ancestry can carry back their lineage to *Pseudastacus pustulosus* and *Eryma modestiformis* in the Jurassic rocks of Solenhofen in Bavaria.

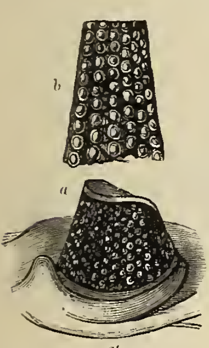


Fig. 26.—EYE OF TRILOBITE.

a, the eye; g', the glabella; b, some of the lenses, greatly magnified.

The eyes in the higher Crustacea, like those of insects, are exceedingly complex structures (Fig. 25), composed of a great number of separate lenses closely compacted together, each having its cornea, its crystalline cone or lens, its pigment, and its nerve-fibre connecting it with the optic nerve. They present every variation, however, between this compound eye in the Decapoda down to the simple eye spot in the Entomostraca, whilst in some forms, as in *Limulus*, both simple and compound eyes are present on the same head-shield.

These compound eyes existed far back in geological time, and may be seen most beautifully preserved in the heads of many Silurian Trilobites, notably in the genera *Æglina*, *Phacops* (Fig. 26), and *Dalmannia*, whilst *Pteryotus*, like *Limulus*, had both compound eyes and simple ocelli. The eyes are the most constant and persistent organs possessed by the Crustacea as a class; indeed, if we except certain parasitic Isopodous forms and the Cirripedia and Rhizocephala, we shall find that the faculty

of sight is peculiar to the whole class. Even in those exceptional cases in which the eyes are aborted, we find that in the earlier and larval stages of their existence the parasitic and sedentary forms possessed eyes, and it is only as the effect of a kind of retrograde metamorphosis which the animal undergoes that the organs of vision disappear in the adult.

"The Brown Shrimp" (*Crangon vulgaris*) seems peculiarly an estuarine form, being taken in large quantities in Morecambe Bay, Lancashire, the Lynn Wash on the Lincolnshire coast, the Thames from Gravesend to the sea, and in the estuary of the Seine, especially near Honfleur. It is of a drab colour, dotted over with brown spots, and it does not become red by boiling as most other Crustaceans do. Its greatest length is two inches and a half (Fig. 27).

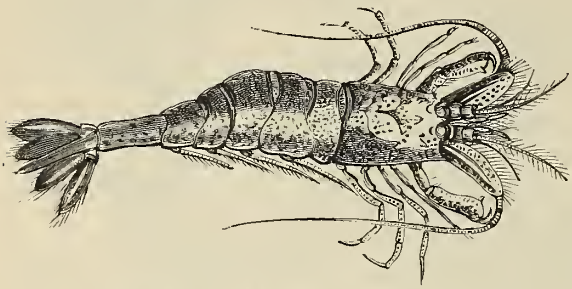


Fig. 27.—THE COMMON BROWN SHRIMP (*Crangon vulgaris*).

The absence of the prominent serrated beak or rostrum, so marked a character in all the *Palæmonidæ* (Prawns and Shrimps proper), at once enables the collector to separate the Crangonidæ therefrom. The chelæ of the fore hand are present in *Palæmon* but absent in *Crangon*, in which the fixed thumb is rudimentary.

A small but interesting little shrimp-like Crustacean, named *Alpheus*, which occurs only rarely with us, but is abundant on the shores of Guernsey, Herm, and other of the Channel Islands, and one species in particular of which, the *Alpheus ruber*, is of a bright pink or salmon colour, has one claw of the first pair much more largely developed than the other, whilst the second pair are weak, slender, and many-jointed. This character in the second pair of legs is also observable in the genus *Nika*, closely allied to *Alpheus*.

All the members of this family (*Alpheadæ*) are remarkable for the loud clicking noise which they habitually emit. It does not seem certain whether this sound, which is always accompanied by a sudden opening of the great claw to the fullest extent, is produced by impact of the heavy movable joint of the chela against the fixed ramus or by the forcible withdrawal of the huge stopper-like tooth from its pit in the penultimate joint of the claw. (Wood-Mason.) Col. Stuart Wortley remarks, "Keeping them as I do in an aquarium, it is startling sometimes in the evening to hear the loud snap produced by sharply striking together the two claws on the larger leg."

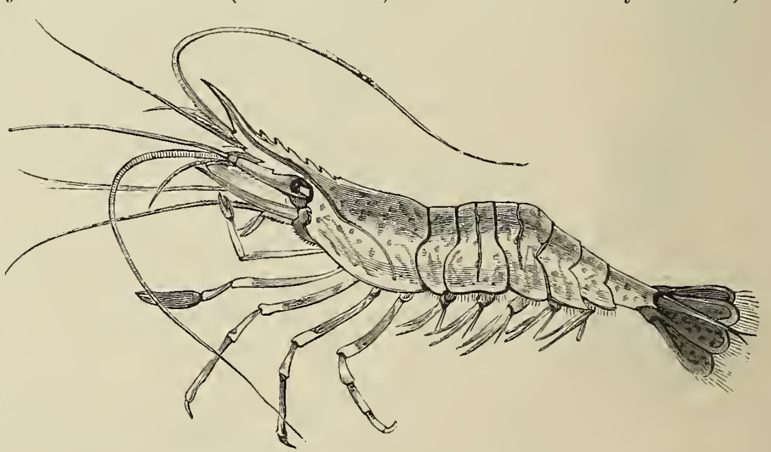


Fig. 28.—THE COMMON PRAWN (*Palæmon serratus*).

Palæmon serratus, the common Prawn (Fig. 28), which is so well known as a favourite and delicate article of food, is found in vast numbers on the south coast of England. It appears from various accounts that it approaches the shore in its young state, and multitudes of them are taken in shrimp-nets and sold as Shrimps. At Bognor the fishermen consider them, when young, as a distinct species, and assert that, at certain seasons, they drive the true Prawns from their ordinary place of resort. The probability is that, at the season when the young ones have arrived at a certain size, they separate themselves from the older ones, which at that period of the year retire farther from the shore. At Poole the young ones of this species were commonly found associated with two other species of *Palæmon*, and the three are ordinarily sold there under the name of "Cup Shrimps," being measured in small cups instead of being sold by tale, as they are when larger. When of middle size

they still retain the name of Shrimps at that place, and are only called "Prawns" when they acquire larger dimensions.

Calocaris Macandreæ (Bell). This little Crustacean, which is found living at a depth of nearly two hundred fathoms, is fossorial in its habits, burrowing in sandy mud. Its eyes are quite rudimentary, being destitute both of pigment and cornea. Many Crustaceans obtained from great depths in the Swiss lakes prove to be blind. This is also the case with several species of Crustacea met with in the great Mammoth Cave and in the caverns of Carniola and Adelsberg.

Dr. A. S. Packard has described a Cray-fish, named *Cambarus pellucidus*, an Amphipod (*Niphargus stygius*), and two Isopods (*Titanethes albus* and *Cæcidotea stygia*), from the Mammoth Cave, Kentucky, all of which are blind. "The eyes," says Dr. Packard, "in *Cambarus*, are rudimentary in the adult, but are larger in the young. This is evidence that the embryo develops like those of other species, and that the inheritance of blindness is probably due to causes first acting on the adults and transmitted to their young until the production of offspring that become blind becomes a habit."

Both *Niphargus* and *Crangonyx*, two forms of *Gammaridæ*, have been obtained in this country from wells and pumps in the Chalk and Oolite formations. They are wholly or partially blind.

CHAPTER III.

CRUSTACEA (*concluded*).

STOMAPODA—*Squilla*—*Mysis*—ISOPODA—*Bathynomus*—*Tanais*—The "Gribble"—*Asellus*—*Arcturus*—*Sphæroma*—Parasitic Forms—AMPHIPODA—The "Sand-hopper"—*Orchestia* and other Forms—Aberrant Amphipods—XIPHOSURA—King Crabs—Character—Habits—EURYPTERIDA—TRILOBITA—PHYLLOPODA—Character—CLADOCERA—OSTRACODA—COPEPODA—Parasitic Forms—CIRRIPEDIA—RHIZOCEPHALA—BALANIDÆ—LEPADIDÆ—Barnacles.

ORDER II.—STOMAPODA (MOUTH-FOOTED).

IN the STOMAPODA we find a considerable divergence from the DECAPODA already noticed. Taking *Squilla* as an example, the segments are much less coalesced than in the Lobster. Those bearing the eyes and antennules are readily separated from the front of the head, and are not covered by the carapace, which only conceals eight segments, whereas in the Lobster it extends over fourteen. The gills are no longer attached to the thoracic appendages, and enclosed in a branchial chamber formed by the head-shield, but they are transferred from the thoracic limbs to the abdominal swimming-feet, and are free and uncovered.* The first thoracic appendages are developed into a pair of robust claws, the terminal joint being furnished with a row of long and sharp re-curved teeth, which can be doubled back upon the penultimate joint, which has a groove to receive it like a pocket-comb. Armed with these two innocent-looking toilet requisites, *Squilla* goes about seeking whom he may devour.

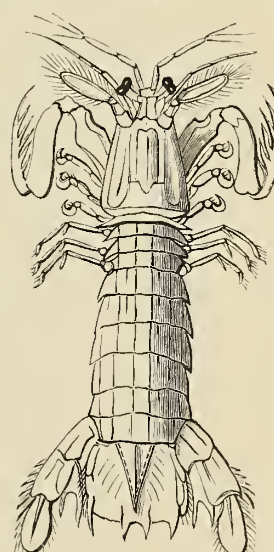


Fig. 29.—SQUILLA MANTIS.

In another genus belonging to this order (*Mysis*, or the "Opossum Shrimp," Fig. 30) special branchiæ seem to be absent, their duty being performed by the series of flabelliform appendages attached to the pedipalps, or thoracic feet, certain of which are modified in the female to form a "pouch," or marsupium, in which the eggs are protected and the young retained whilst passing through their earlier stages of existence.

These Opossum Shrimps are frequently met with in countless myriads towards the surface of the Greenland Sea, and, small though they be, they form the chief part of the food of the Common Whale (*Balæna mysticetus*), by which such a quantity of fat is accumulated. It seems at first sight incredible that so large an animal can be supported on so slender a repast, but, as in eating Whitebait, numbers must count, and doubtless the Whale devours many hundreds of thousands at each mouthful.

* Hence they might aptly be termed *naked*-gilled Crustacea.

From the stalk-eyed *Podophthalmia* we pass to the sessile-eyed *Edriophthalmia*, Crustaceans in which (with few exceptions) the eyes are fixed immediately on the surface of the head. As in the higher forms, the eyes are compound, consisting in the young of some ten or twelve lenses only, but in the adult of as many as from sixty to eighty. The head-shield in the Crab and Lobster encroaches so far upon the body-segments as frequently to conceal them, whereas in the EDRIOPHTHALMIA the head-shield only covers the seven first, or head-rings, the seven thoracic segments being well developed in both divisions and the seven abdominal also in the Amphipoda, but in the Isopoda they are mostly coalesced together. The body in the Amphipods is compressed at the sides, whereas in the Isopods it is mostly broad and flattened in shape. Thus the Isopods and Amphipods form two very natural groups, which are comparable to the Crabs and Lobsters, the Isopods resembling the former and the Amphipods the latter in shape.

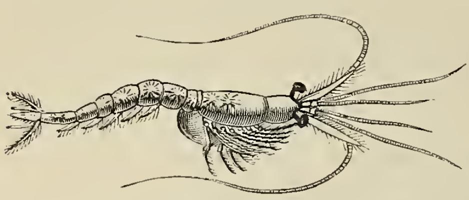


Fig. 30.—OPOSSUM SHRIMP (*Mysis chamæleon*).

SECOND LEGION.—EDRIOPHTHALMIA.

ORDER III.—ISOPODA (EQUAL-FOOTED).

The ISOPODA are so named in allusion to the general conformity in size and function of the seven pairs of legs, the two foremost pairs of which in the AMPHIPODA are equivalent to the two outer pairs of jaw-feet in higher Crustacea.

In the DECAPODA, STOMAPODA, and AMPHIPODA, the branchiæ (in each case) are attached to the base of the legs. In the *Isopoda*, on the contrary, the posterior (abdominal) appendages are converted into special organs of respiration, in the form of leaf-like appendages. The heart is also near the tail. The body is composed of seven segments, generally nearly equal in size. To these, in the normal Isopods, seven pairs of nearly uniform legs are attached, either fitted for walking, swimming, or as powerful hook-like organs which enable them to adhere firmly to the fishes upon which many of them are parasitic.

One group of Isopods, the *Oniscidæ*, familiar to us in gardens under the name of the Common Wood Louse, are all air-breathers—not residing in water, but in damp situations—breathing air, which, however, it is necessary should be saturated with moisture. Several of the species which inhabit caves are destitute of eyes, *e.g.*, *Titanethes albus*, from the Mammoth Cave, Kentucky. The Great Sea-Slater (*Lygia oceanica*) is common on all our coasts, running with agility, and folding up, so as to feign death, when attacked.

One of these, found in our gardens and woods, the *Armadillo* (also named the "Pill Bug" in America), from the perfect way in which the segments roll together, forcibly reminds one of the fossil genus *Illænus Barriensis*, a Trilobite found in the Upper Silurian at Barr, Staffordshire.

Prof. Alexander Agassiz, aided by the United States Coast Survey, has carried on extensive deep-sea dredging operations in the American seas, particularly exploring the bed of the Gulf Stream and the Straits of Florida, between the south point of Florida and the Island of Cuba. Among other Crustacean treasures obtained was a gigantic Isopod, dredged from a depth of 955 fathoms, on the north-east of the bank of Yucatan, and north of Tortugas. This Isopod has been named *Bathynomus giganteus* (Fig. 31) by Alphonse Milne-Edwards. It measures nine inches in length by four inches in breadth, and far exceeds any other living Isopodous Crustacean in dimensions. The gills or branchiæ, which in ordinary Isopods are simple leaf-like appendages, formed out of the modified abdominal feet, in *Bathynomus* consist of a highly complex arrangement of tufts of filaments supported on tubular peduncles covered by a series of opercular plates. Notwithstanding the vast

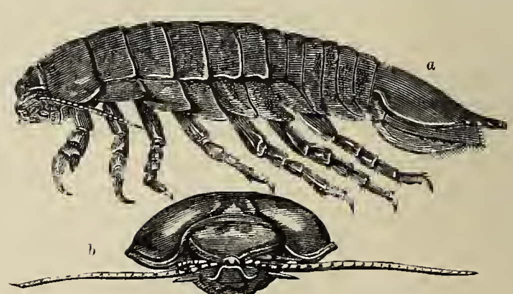


Fig. 31.—A GIGANTIC ISOPOD (*Bathynomus*). *a*, side view; *b*, front view of head.

depth from which *Bathynomus* was obtained, the eyes are greatly developed, each being made up of about 4,000 square facets, and instead of being placed on the upper surface of the head, as in all known wandering *Cymothoidæ*, they are placed below the frontal border of the head at the base of the antennæ. Alphonse Milne-Edwards places *Bathynomus* in a new family of the division *Cymothoidæ*, named *Cymothoidæ branchiferæ*.

In *Tanais* (Fig. 32)—an aberrant form of Isopod—the first pair of legs are converted into chelæ, the six other pairs being simple, as in other Isopods. This peculiarity, and the confluence of the head with the first segments of the body, give it a very Macrouran aspect. In some the eyes are prominent, and almost pedunculated. This group also presents many points of affinity with the AMPHIPODA.

Fig. 32.—TANAIS, A REMARKABLE ISOPOD.
A, the flabelliform appendage under the carapace in the rudimentary branchial chamber.

To the Isopodous division belongs the *Limnoria terebrans*, or the "Gribble," as it is commonly called by fishermen. It is a most destructive creature, attacking all woodwork below tide-mark, the only wood which it cannot destroy being teak. Although its ravages had gone on for centuries, it was only in 1811 that it was discovered and described by Dr. Leach.

The *Asellus aquaticus* is a very abundant form, inhabiting fresh-water ponds and ditches. The eggs and the young are retained in the pouch of the mother for about six weeks; probably half this period elapses before the young quits the egg. *Asellus* does not exceed six lines in length, and little more than half a line in breadth. It feeds upon vegetable matter exclusively. The leaves of the beech in decay are preferred, and in the parts of the pond where these are most abundant, there the *Asellus* is most numerous. The animal does not generally swim, it runs freely and expeditiously over the decaying leaves.

In *Arcturus* the young are carried by the parent in rows upon the long joints of its antennæ, the mother remaining in a nearly erect position clinging to a branch of some zoophyte or seaweed, along which she can walk by means of her hind feet. Until the discovery of *Bathynomus giganteus* by Agassiz (a form belonging to the *Cymothoidæ*), the *Idoteidæ* were supposed to contain representatives of the largest known Isopods, some of which measure about four inches in length. The hinder segments are welded together so as to form a long caudal shield, beneath which are two plates covering the branchiæ.

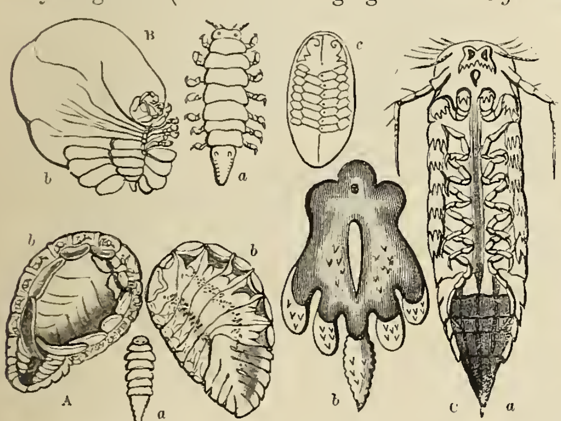


Fig. 33.—PARASITIC ISOPODS: BOPYRUS (A), PHRYXUS (B), CRYPTOTHYRIA (C).
aa, males; *bb*, females; *c*, larva.

The genus *Sphæroma*, the members of which are vegetable feeders, are also found guilty of destroying timber. When molested or alarmed, they roll themselves up into a ball. This genus and its allies offer many points of analogy, if not of affinity, with the extinct Trilobites.

Several species among the Water Breathers are parasitic, often on members of their own class. Thus in *Bopyrus* (Fig. 33, A) the female (which is six times as large as the male) is parasitic within the branchial chamber of the Common Prawn, and out of six Prawns, it is no uncommon thing to find one or more with this parasite distorting the carapace of the Prawn on one side. When the Prawn moults his shell, the *Bopyrus* manages to retain its situation, and re-appears with the new shell of the Prawn accommodating itself to the form of the *Bopyrus*. *Pagurus*, *Galathea*, *Callianassa*, *Porcellana*, *Palæmon*, and *Hippolyte*, all have these parasitical Crustacea in their branchial chamber. Another genus (*Phryxus*, Fig. 33, B) attaches itself beneath the tail of the Prawn, and we have taken it also from beneath the abdomen of the Common Shore Crab at Torquay. It is more curious still to note a parasitic Isopod, the female of which occupies the cavity within

the shell of the living *Balanus balanoides*. A second species, also referred to the genus *Cryptothyria* (Fig. 33, c), is found resident within the body of another Cirripede (*Peltogaster*), which itself is parasitic on the tail of a Crab (*Portunus* or *Carcinus*). Those belonging to the genus *Æga* have all the feet furnished with a robust curved finger, sharp at the tip for seizing and holding on to fishes, as the Codfish, Whiting, &c., to the exterior of which they adhere. The *Eurydice pulchra*, common in the River Dee in Cheshire, will actually fasten upon bathers if they remain quiet in the water, adhering to the skin even after they emerge from the river.

ORDER IV.—AMPHIPODA.

In the Amphipoda the head is small, representing only the first seven cephalic rings, the seven thoracic and the seven abdominal being nearly equally well developed. The eyes are sessile or fixed, the body-rings are compressed laterally, as in the Lobster, and they possess both swimming and walking legs—indeed, we might add, leaping ones also, for many of them pass much of their time in this mode of progression on our shores. The first and second pairs of appendages become modified, in the male, into strong claspers, by the greater development of the hand and the movable character of the terminal joint, whilst the last pair of limbs are converted into leaping legs, like those of the Grasshopper. The gills are attached to the thoracic feet, as is also the incubatory pouch of the female. The heart lies beneath the dorsal surface of the body. To this division belongs the well-known "Sand-hopper" (the *Talitrus locusta* of Linnæus), one of the most abundant forms everywhere around our coast, living between high and low water-mark, where it feeds on decaying garbage, both animal and vegetable, existing in myriads on some of our sandy shores. They never enter the water, but yet seem to require a certain amount of moisture to enable their branchiæ to perform their function. They burrow under moist seaweed and in damp sand. The young *Talitrus* usually remains with the parent for some time after they attain to maturity.

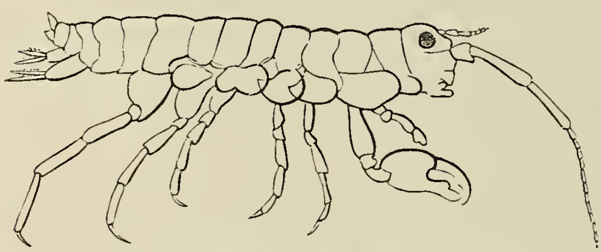


Fig. 34.—An amphipod (*Orchestia Darwinii*), male.

Another genus (*Orchestia*) also lives out of the sea, choosing moist places, but not burrowing as *Talitrus* does. With us *Orchestia* lives within the reach of the sea-spray, but some species in the Southern Hemisphere live many miles inland, choosing terrestrial plants for their abode. They are sometimes found at 1,500 feet above the sea-level (Fig. 34).

Sulcator lives along the sea-margin, making tracks upon the sandy shore, which, when in after years they have become hardened into sandstone, form puzzles for the palæontologist, who finds it sometimes difficult to decide whether they are worm-tracks or impressions of plants.

Blind species of *Niphargus* and *Crangonyx* are found inhabiting our subterranean fresh waters in wells in the Chalk and Oolitic rocks of various parts of England and Europe. One species of *Niphargus* inhabits the hot springs of Italy.

The *Chelura terebrans* is one of the most injurious xylophagous Crustaceans known. It is commonly found associated with another wood-borer, the *Limnoria lignorum* (the Gribble), an Isopod, which, though smaller, is even more prolific than *Chelura*. The excavations made by *Chelura* are larger and more rapidly executed than those of *Limnoria*.

In all these forms an extreme degree of maternal solicitude seems to be developed, which exhibits itself not only in carrying the young, after hatching and brooding over them like a hen over her chickens, but in *Podocerus* the parent builds a nest in which the young are nurtured and protected, more after the manner of young birds than of such comparatively lowly-organised forms as Crustacea.

The Læmodipoda form (according to Spence Bate and J. O. Westwood) an aberrant group of Amphipods. The coxal joint of all the legs is fused with the body, and the tail is reduced to a rudimentary condition.

The popular name of Spectre, or Skeleton Shrimp, seems very appropriate to *Caprella* (Fig. 35). It lives amidst seaweeds and zoophytes, and is very active, scrambling from branch to branch.

"Their usual mode of progression is compared by Fabricius, Goodsir, and Gosse, to that of the larvæ of the Geometric Moths. They sometimes walk in this way for a considerable time, and then suddenly stop, remaining perfectly motionless, not even moving their antennæ. They seldom attempt to swim, and will, when placed in the water, independently of anything to rest upon, generally drop to the bottom." Like all the lower Crustacea, the *Caprellæ* cast their skins often. Before the process commences, the animal lies for a time to all appearance dead.

The Skeleton Shrimp carries its ova in an incubatory pouch, which is developed when required. "It consists of four plates, two attached to the third and two to the fourth segment of the body, arising upon the under surface and the inside of the branchiæ. As soon as the young are old enough to enjoy a separate state of existence they quit the protection of the pouch in which they have been nurtured, and, passing out, climb, gipsy-like, to the back of their mother, where they are seen holding on in every conceivable attitude. In the British Museum is preserved a specimen of an exotic species in which death has not separated the parent from her offspring. They may be seen attached, as if climbing from the incubatory pouch to the back of the parent."

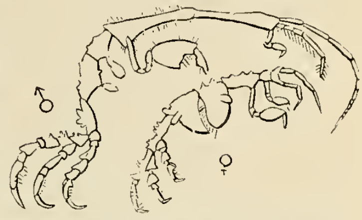


Fig. 35.—THE SPECTRE, OR SKELETON SHRIMP (*Caprella*).

THIRD LEGION.—MEROSTOMATA.

ORDER V.—XIPHOSURA (KING CRABS).

The *Merostomata*, or "thigh-mouthed Crustacea," are represented to-day by the Horseshoe Crabs of America (Fig. 36) and the King Crabs of the China Seas (Fig. 37). There is only one living genus (*Limulus*), but it is found as far back in time as the Lower Secondary rocks, whilst forms, differing but little from those now existing, occur pretty numerously in the Coal-measures of England and America, and one is found so far back as the Upper Silurian formation. The soft parts are encased within a double shield-shaped shell divided into two parts, the first representing the head and the second the thorax and abdomen. The eyes are fixed on the anterior surface of the head-shield, beneath which are the walking limbs. The abdomen, however, is quite rudimentary, being partly represented by the posterior portion of the hind or thoracic shield, and partly by the long ensiform tail-spine. Under the hinder shield the leaf-like gills are placed. But in the larvæ we find the body-segments free and unanchylosed, and the tail-spine undeveloped, thus bearing out the characters common to the class, and connecting the living *Limulus* of to-day with its far-off ancestors in the Coal and Silurian periods. The limbs are all attached to the head, and correspond to the antennæ and the jaw-feet of the Crab and Lobster. They are, however, called upon to fulfil the double office of jaws and legs, which they do most

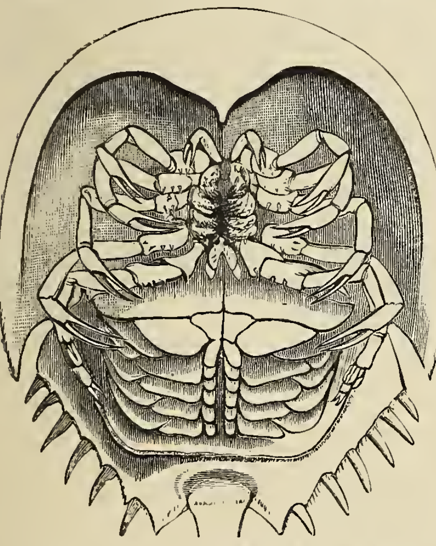


Fig. 36.—THE HORSESHOE CRAB (*Limulus polyphemus*), UNDER SURFACE SHOWING JAWS.

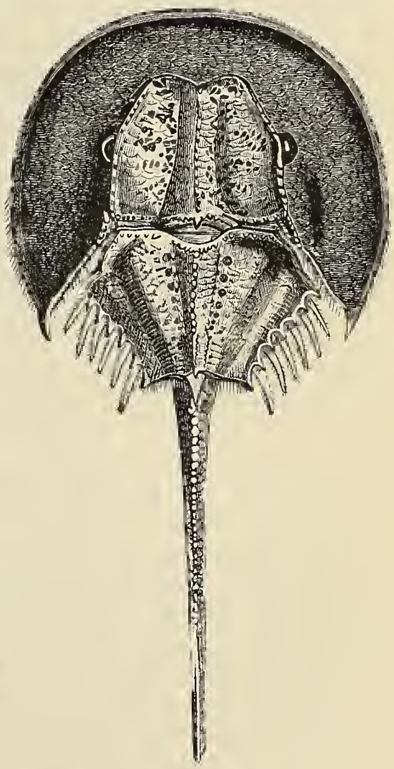


Fig. 37.—THE KING CRAB (*Limulus moluccanus*).

effectually. All the feet (save the little pair in front of the mouth) act as jaws, and they all have nippers or pincers at their extremities. The limbs of the thorax are converted into broad plates covering the ovaries and gills, and we find the last pair of feet are furnished with brooms with which to keep these delicate organs clean. Its eyes are placed upon the upper and anterior surface of the great shield-shaped cuirass or carapace, and it is furnished both with compound eyes, which resemble those of a Trilobite in form and position, being placed on each side of the head-shield, and also with a pair of larval ocelli or simple eyes placed just in the front of the head-shield.

Dr. S. Lockwood writes—"The King Crab delights in moderately deep water, from two to six fathoms. It is emphatically a burrowing animal, living literally in the mud, into which it scoops and gouges its way with great facility. The anterior edge of its enormous cephalic shield is not unlike in form to a cheese-cutter. The upper shell of the animal is composed of three parts—the forward shield, which is greatly larger than the posterior shield, and the long bayonet-shaped spine or tail. In the burrowing operation the forward edge of the anterior shield is pressed downward, and shoved forward, the two shields being inflected, and the sharp point of the tail presenting the fulcrum as it pierces the mud, while underneath the feet are incessantly active, scratching up and pushing out the earth on both sides. There is a singular economy of force in this excavating action, for the alternate doubling up or inflecting, and straightening out of the two carapaces, with the pushing purchase exerted by the tail, accomplish both digging and subterranean progression. The *Limulus* is carnivorous, its food being the soft nereids or sea-worms. The King Crab has six pairs of feet; the extreme anterior pair are called antennæ, being greatly shorter than the others. Of the four pairs between this pair and the last pair, the basal joint of each limb is flattened and smooth on each side, as though they were a series of plates intended to work upon each other. The external edge of each is rounded, and bevelled like a carpenter's chisel. Thus these flattened haunches lie against each other, their rounded edges directed backward at a considerable angle. The bevelled edges of these projections are covered with very sharp incurved spines, overhanging and pointing into the oral aperture, for it is between these five pairs of spine-clad haunches that the creature's mouth is situated. These, then, are the true jaws of the animal's mouth, and as there are five pairs of these manducatory joints, the creature's mouth is set in a line between ten joints. These spiny teeth have, by their articulation, an amount of mobility in their little pits which is eminently serviceable. Of these chewing teeth an individual can scarcely have less than one hundred and fifty."

It is extremely interesting to notice the occurrence at the present day of two living species of *Limulus*, one confined to the Moluccas and to the coast of China, the other to the eastern shores of North America, having continuous land separating them from each other from Tierra del Fuego to the Strait of Magellan. It speaks of the great antiquity of this genus, which has survived vast changes in the present configuration of land and sea, more even than is involved by the subsidence of the Panama Isthmus.

ORDER VI.—EURYPTERIDA* (EXTINCT).

ORDER VII.—TRILOBITA† (EXTINCT).

The sixth and seventh orders—the *Eurypterida* and the *Trilobita*—are both extinct, and have not been found, even in a fossil state, in any rock of younger age than the Carboniferous Limestone.

The *Eurypterida* are nearly related to the King Crabs, but the body-segments are distinct, not soldered together, as in *Limulus;* but in both *Limulus* and *Eurypterus* the limbs serve the double office of jaws and feet, being masticating organs at one end and clawed feet at the other.

The Trilobites form one of the oldest groups of fossils known. Superficially, they closely resemble the living Isopods; but they have often more, and sometimes fewer, than seven free segments between the head and tail—a number nearly constant among the Isopods.

The appendages, too, of the Trilobites appear to have been quite different from those of Isopods.

* Greek, *eurus*, broad, and *pteron*, a wing (broad-wing), in allusion to the feet and to certain parts of Pterygotus, supposed by Louis Agassiz to have belonged to scaly fishes.

† Greek, *trilobos*, three-lobed, so named because all the segments of the body are corrugated, like a piece of iron or zinc roofing, into three arches.

FOURTH LEGION.—BRANCHIOPODA.

ORDER VIII.—PHYLLOPODA (LEAF-FOOTED).

The Branchiopoda, or Gill-footed Crustacea, form the first division of the Entomostraca, or "Shelled Insects," so called because most of its members are more or less entirely invested in a shelly envelope.

They are all aquatic, the greater part having a shell composed of two parts or valves, in which they are more or less completely enclosed, or in the form of a buckler, which envelops a large part of the animal. Their gills are attached to their feet, or to their jaw-feet. Like the higher class of Crustacea, they moult their shell and skin frequently.

Of the shield-bearing form of Phyllopoda (Fig. 38), the fresh-water *Apus* may serve as a good example. The eyes are placed on the dorsal surface of the carapace, and are nearly united. The antennæ are short and simple; the first pair of feet are very long and branching; these are followed by about sixty pairs of branchial feet. The thorax and abdomen are nearly cylindrical, and are composed of about thirty articulations, terminated by two long, many-jointed tail-spines.

Apus affords a good example of a form in which the mere vegetative repetition of parts is carried to an extreme distance beyond the normal number of body-rings so characteristic of the Crustacean class. Probably *Apus* has more articulations to its appendages and body than any other Crustacean. Schäffer tabulated them, and found they numbered 1,802,604; Latreille puts them down at not less than 2,000,000.

In *Nebalia*, the marine type, the head-shield is more arched, covering the body as in a bivalved shell. The eyes are pedunculated, and placed beneath the carapace. The number of segments is not excessive.

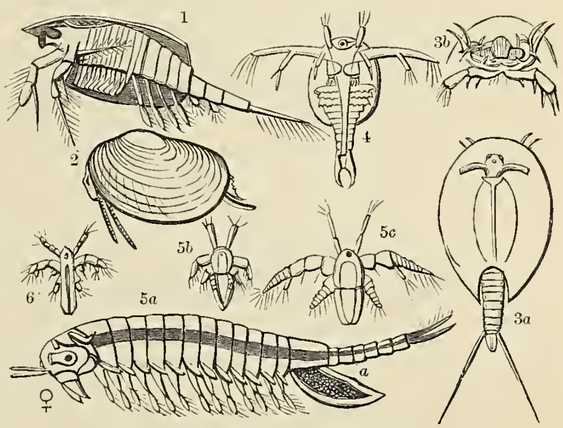


Fig. 38.—PHYLLOPODA.

1, *Nebalia bipes* (shell partly removed): 2, *Estheria*, sp.; 3, *Lepidurus Angassi*—*a*, dorsal aspect, *b*, ventral aspect; 4. Larva of *Apus cancriformis*; 5, Branchipus (Cheirocephalus) stagnalis—*a*, adult female, *b*, *c*, larvæ; 6, Larva of *Artemia salina*.

Otho Fabricius says that "the female carries her eggs beneath the thorax during the whole winter; these begin to hatch in April, and appear in May, when they are very lively, and adhere to the mother. The adult is not very active. On our coast they are found under stones, lying on mud amongst hollows of rocks."

The genus *Estheria* deserves to be especially mentioned on account of its wide distribution at the present day, and also because it has a very long past geological history. Its oval, bivalved shell has often been mistaken for that of a mollusc.

In *Cheirocephalus* and *Artemia* the shelly shield is altogether wanting, and their elegant movements in the water can be freely observed. The former inhabits fresh water; the latter is marine.

ORDER IX.—CLADOCERA.

In the Cladocera* the body, save the head, which is projecting, is entirely enclosed within a carapace, formed by the two valves of the shell. The eye is single and very large; the four to six pairs of feet are branchiform, the two large pairs of antennæ serving as organs of locomotion. Of this order, the Common *Daphnia pulex* (Fig. 39) of our fresh waters is the best example we can take, not only on account of its abundance, but also because it has formed the subject of numerous memoirs by Professor Leydig and others. So plentiful are they in some ponds as to impart a blood-red hue to the water frequented by them. In order to apprehend the wonderful fecundity of this and allied genera, it is necessary to realise that a *Daphnia*, under favourable circumstances of temperature, may have three broods a month, or even a greater number, some of the larger species having as many as forty or fifty eggs at one brood!

"At particular seasons the *Daphniæ* may be found with a dark opaque substance on the back of

* Greek, *klados*, a branch, and *keras*, a horn; hence branching-horned, in allusion to their antennæ.

the shell. This is what Müller calls the ephippium, from the resemblance it bears to a saddle. But though he describes it well, he does not give any opinion upon the cause or use of the formation. Straus, however, has proved it to be an inner bivalved case or shell, containing two eggs, destined, he says, for perpetuating the species in the spring: these eggs resisting the cold of winter, which proves fatal to the perfect animal."

FIFTH LEGION.—LOPHYROPODA.

The LOPHYROPODA, or stiff Hair-footed Crustacea, form the second division of the *Entomostraca*. The same simple structure is repeated as in the BRANCHIOPODA, with but slight variations in the organs of locomotion.

ORDER X.—OSTRACODA.

In the fresh-water *Cypris* and the salt-water *Cythere* the body is enclosed in a bivalved shell. Dr. Baird says of *Cypris*:—"When the ponds and ditches in which they live dry up in summer, they bury themselves in the mud, and thus preserve their lives as long as the mud retains any moisture, becoming as active as ever when the rain falls and again overflows their habitation. After long-continued drought, however, when the mud becomes very dry and hard, they perish; but the eggs do not perish with the parents, for they can be hatched in four days after being placed in water. These little creatures seem to be very lively in their native element, being almost constantly in motion, either swimming about rapidly by the action of their antennæ, or walking upon the plants and other solid bodies floating in the water."

The *Cythere* are minute marine Crustacea, and are met with in pools amongst the rocks along the coast. "These animals," says Dr. Baird, "have never been seen to swim, invariably walking among the branches and leaves of the Confervæ or Fuci, &c., where they delight to dwell. When shaken out from their hiding-places into a bottle or tumbler of water, they may be seen to fall in gyrations to the bottom, without ever attempting to dart through the watery element, as is the case with the Cyprides. Upon reaching the bottom, they open their shells and creep along the surface of the glass, but when touched they immediately again withdraw themselves into their shell, and remain motionless. Their inability to swim is, no doubt, owing to the want of the pencils of long hairs or filaments which adorn the superior and inferior antennæ of the Cyprides."

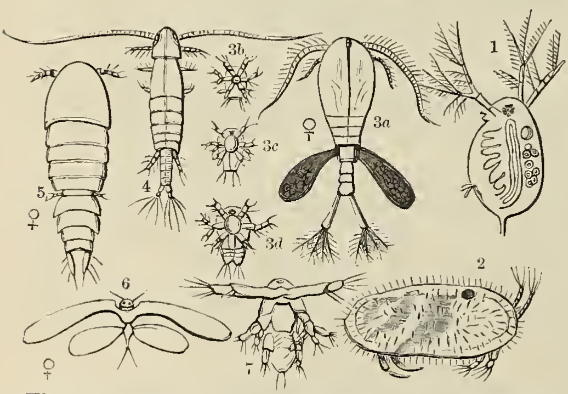


Fig. 39.—FORMS OF CLADOCERA, OSTRACODA, AND COPEPODA.
1, *Daphnia pulex*, fresh water; 2, *Candona hispida*, fresh water; 3, *Cyclops quadricornis*, fresh water—*a*, adult female, *b*, *c*, *d*, larvæ; 4, *Cetochilus septentrionalis*, Firth of Forth; 5, *Sapphirina ovatolanceolata*, Atlantic: 6, *Nicothoë astaci*, parasitic in gills of lobster; 7, Nauplius stage of Copepod.

ORDER XI.—COPEPODA.

In the fresh-water *Cyclops* and the marine *Cetochilus* (Fig. 39) the head and thorax are covered by a shield, and the posterior abdominal segments are distinctly seen. The long antennæ in the latter forms serve as oars to propel the animal through the water. How great must be the numerical strength of the species in these lower forms, when *Cetochilus* so minute can yet colour the sea for miles in extent, and furnish abundant food for so large a mammal as the Whale!

The various species of the genus *Cyclops* abound in inland waters all over the world, being essentially fresh-water animals, in a few cases only inhabiting slightly brackish water. They are amongst the most abundant of all the individuals of the order. The young stages of Cyclops have been named as distinct species, the same animal having been honoured with four or five different titles between birth and maturity. The full-grown female is often of considerable size. The eggs are carried in pouches, and are not dependent on the mother, but will come to maturity if separated from her. The eggs vary in number, old individuals laying upwards of forty. It has been calculated that in one year a female would become the progenitor of 4,442,189,120 young, so that the abundance

in which they are met with is not strange, notwithstanding their many enemies. The *Cyclops* feeds both on animal and vegetable matter.

The *Cetochilus*, or "whale-food," is one of the small Entomostraca, known to the fishermen of the Firth of Forth by the name of *maidre*, on which the Herring and many fine species of Salmonidæ live almost exclusively. These small Copepods abound in such quantities as to obscure the water; immense shoals of Cod-fishes are seen swimming lazily about, devouring them in large numbers. Shoals of Herrings are also seen pursuing them with great agility.

The Parasitic Copepoda may be divided into two groups. The first comprises the free-swimming genera, in which both the male and female retain their organs of locomotion in the adult state, and can change their habitat whenever needful. This division includes the fresh-water *Argulus* and the marine *Caligus*. The second division includes the fixed parasites, in which the females, when adult, lose their locomotory appendages, and become fixed, deriving their nourishment by a true suctorial mouth, armed with jaws for piercing the tissues of the fishes and other animals upon which they are parasitic; the males, however, remaining free.

"The Argulus in this country is found upon various fresh-water fishes. In the neighbourhood of London it is most commonly to be met with upon the Stickleback, but it has been taken also upon the Carp and the Roach; and in other places it has been found upon the Trout, the Pike, the Perch, and even upon the tadpole of the Frog."

Professor Dana described a species taken in the Mill River, near Whitneyville, into which the tide runs, thus showing that Argulus can live in brackish water.

Loefling states that the part where *Argulus foliaceus* is chiefly found is within the gills, or immediately outside; and Dana and Herrick inform us that their *Argulus catostomi* was always found within the branchial cavities, but when the fish itself was immersed in fresh water, the parasite forsook the gills, and, after swimming about some time, would often attach itself to the anterior part of the body. The number of eggs deposited by one *Argulus* is very considerable. Dr. Baird says as many as 400 have been laid by *A. foliaceus*, and 1,500 and upwards by *Argulus catostomi*.

Caligus and other allied genera are called *fish-lice*, and are observed to infest the Cod and the Salmon; they are marine Crustacea. Dana says the *Caligi* are most numerous on half-grown fish, and occur on the head and different parts of the body, but never within the gill-covers or under the scales. Dr. Baird says of the European species that they live under the scales, and are often found on the parietes of the mouth and branchial cavities. "When disturbed, they move with rapidity over the fish, and either backward or forward with nearly equal facility. In swimming, their motion is equally rapid. They thus travel over the fish at will, and, we do not doubt, occasionally leave one fish for another."

Both sexes frequently occur on the same fish, though the females are the more abundant. The sizes of the individuals vary, but the adult male often is two thirds of an inch in length. The females are seldom more than half an inch long, and are always smaller than the males.

"The *Caligi* live several hours on the body of the Cod taken from the water, but generally die soon after the death of the fish. When taken from the fish and confined, they exhibit a strong inclination to leave the water. These animals, like the Cod on which they live, require a low temperature, and have been observed to swim, with scarcely diminished activity, in water that was freezing. In some instances, when the water had evidently reached a temperature below 32° Fahr. without congelation, they have been rendered torpid, and apparently dead; but on bringing them into a room not above 45° Fahr., they have soon resumed their usual activity."

The *Caligi* change their skin, as well as the other Entomostraca, but little is yet known of the process. The young, when first hatched, closely resemble the young *Cyclops*, and, like them, undergo a series of moults, or changes of skin, before they become perfectly developed.

Nicothoë astaci, a very small species, of a rosy colour, attaches itself to the gills of the common Lobster (Fig. 39).

The Lerneadæ (fixed parasites) fasten themselves to the eyes and various parts of the bodies of fishes in different ways—some by means of the foot-jaws alone, others by a series of horns proceeding from the side of the head, and others, again, by two long appendages, which spring from the upper part of the thorax, which unite at the tip, and form a sort of round button.

"In general, it is only the adult female of the Lerneadæ that we are in the habit of observing; and in an animal whose organs of motion and perception for the most part are merely rudimentary, and whose existence is strictly stationary, the manner of life must be very simple. Immovably fixed upon the fish which serves it for food, its existence depending upon the life of its host, it requires neither feet to transport it from place to place, nor eyes to guide it in search of fresh abodes. In fact, the whole of its active existence consists in the two operations of taking food and propagating its species. We find them in all instances deeply fixed in the tissue of the parts upon which they have taken up their habitation, and often so deeply lodged that little else but the oviferous tubes are visible externally. These small parasites have been found adhering to the gills of the Dory, the Sole, the Gurnard, and the Salmon, to the fins and gills of the Cod, Haddock, and Whiting, and to the sides of the Carp, Bream, and Roach."

Scoresby, the Arctic voyager, mentions a species of *Lernæopoda* found adhering to the eye of a Greenland Shark; the arm-like appendages were buried in the cornea, to the depth of nearly a fourth of their length. The Sharks thus attacked seem to be rendered blind by their pigmy assailants. "The sailors," says Captain Scoresby, "imagine this Shark is blind, because it pays not the least attention to the presence of a man, and is, indeed, so apparently stupid, that it never draws back when a blow is aimed at it with a knife or lance."

The "Eye-sucker" (*Lerneonema spratta*) is found fixed by the snout to the eye of the Sprat.

Conrad Gesner, in his "Historia Animalium," 1558, describes the structure and appearance of this parasite, "because," he says, "few people know what this parasite is, as it is very small, seldom to be seen, except at the time of the rising of the dog-star, and then not on many fishes, but only on the Tunny, Sword-fish, and occasionally the Dolphin (and not even on every individual). It adheres so firmly that it cannot be removed without tearing it. It sucks the blood of the fish, like as a leech does, till it falls off through very fulness, and then dies."

SIXTH LEGION.—CIRRIPEDIA.*

ORDER XII.—RHIZOCEPHALA (ROOT-HEADED CRUSTACEA).

In the RHIZOCEPHALA the young are free, and resemble young larval Cirripedia, or the adult *Cypris* and *Candona* (Fig. 39). The adult (female) is destitute of all appendages, and attaches itself by means of root-like prolongations from the head to the body of the host upon or within which it is found.

Thus the female of *Entoniscus* resides within the body of a species of *Porcellana*, lying in a thin-walled sac between the liver, intestine, and heart, and is destitute of eyes or antennæ. The thorax has become an irregular inarticulate sac, beset with enormous brood-laminæ; the long vermiform and extremely mobile abdomen has sword-shaped legs; and swelling out above it in a glandular form, as if in a hernial sac, the heart lies at the base of the first segment.

The young in this singular parasite closely resemble those of *Bopyrus* and *Cryptothyria.*

The genera *Sacculina* and *Peltogaster* are usually found parasitic on the abdomen of the Hermit Crab. The animal appears as a small ovoid or kidney-shaped mass, attached by the head, whilst its roots penetrate deeply into the liver of the Hermit Crab.

The only manifestations of life which these most retrogressively metamorphosed Crustaceans present are powerful contractions of the roots, and alternate expansion and contraction of the body, causing water to flow into the brood-cavity, to be again expelled through a wide orifice.

In 1858 Lilljeborg found what he deemed to be a female *Peltogaster* with an egg-sac; but a careful dissection led to the discovery that another parasite of a higher order, namely, a *Cryptothyria*, had become parasitic upon the parasite. The most curious part of this super-parasitic history is that the roots of *Sacculina* and *Peltogaster* seem constantly to be made use of by two parasitic Isopods—namely, a *Bopyrus* and the *Cryptoniscus planaroides.* These take up their abode beneath the *Sacculina*, and cause it to die away by intercepting the nourishment conveyed by the roots; the roots, however, continue to grow, even without the *Sacculina*, and frequently attain extraordinary extension, especially when a *Bopyrus* obtains its nourishment from them (Fritz Müller).

Let gardeners take a hint from this, and graft some new fruit upon the mistletoe bough.

* Latin, *cirrus*, a curl, and *pes*, a foot; hence, curl-footed.

ORDER XIII.—BALANIDÆ.* ORDER XIV.—LEPADIDÆ.†

Thanks to Charles Darwin, Vaughan Thompson, Goodsir, and Bate, the CIRRIPEDIA, one of the most aberrant groups, have now a place among the Crustacea (Figs. 40, 41). The two great divisions of BALANIDÆ and LEPADIDÆ represent the condition of the adult female, or hermaphrodite; the larvæ, resembling the young of *Cyclops* and *Cypris*, being free-swimming forms, and undergoing a series of metamorphosis, as do some of the highest Crustacea.

"Almost every one," says Darwin, "who has walked over a rocky shore, knows that the Barnacle, or 'acorn-shell,' is an irregular cone, formed generally of six compartments, with an orifice at the top, closed by a neatly-fitted, movable lid, or operculum. Within this shell the animal's body is lodged, and through a slit in the lid it has the power of protruding six pairs of articulated cirri, or legs, and of securing by their means any prey brought by the waters within their reach. The basis is firmly cemented to the surface of attachment. The whole shell, basis, and operculum consists of the first three segments of the head, modified into a singularly constructed carapace, which encloses the mouth and rest of the body. The anterior extremity of the shell is situated in the centre of the basis, where, indeed, by due care, the antennæ of the pupa may be always detected; the posterior extremity is directed vertically upwards."

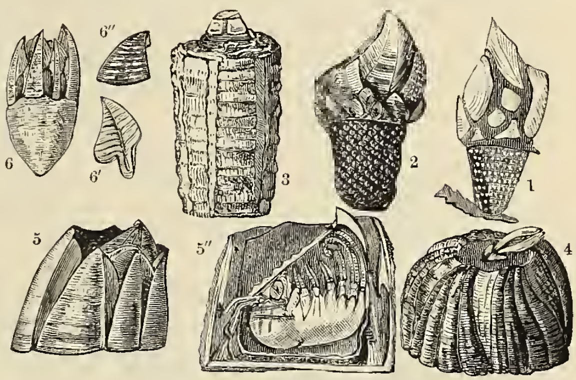


Fig. 40.—CIRRIPEDIA.

1, *Scalpellum rostratum*. Philippines; 2, *Pollicipes cornucopiæ*, European seas; 3, *Tubicinella trachealis*, attached to whales; 4, *Coronula diadema*, attached to whales; 5, *Balanus tintinnabulum*. Atlantic; 5″, section of same showing animal in shell; 6, *Acasta sulcata*, found in living sponges; 6′, 6″, opercular valves of same.

When the period has arrived at which the young *Balanus* or *Lepas* shall assume the adult characters, it attaches itself by its antennæ, which are modified as cement-ducts, and by which it becomes fixed to a suitable body, organic or otherwise, and secretes a shell.

In the one group (*Balanidæ*) the base is fixed and immovable, save the opercular valves; in the other (*Lepadidæ*) the shell is supported on a peduncle more or less movable.

"The Barnacle begins life in a form exactly like that of a young Entomostracous Crustacean, with a broad carapace, a single eye, two pairs of antennæ, three pairs of jointed, branched, and well-bristled legs, and a forked tail. It casts off its skin twice, undergoing, especially at the second moult, a considerable change of figure. At the third moult it has assumed almost the form of *Cypris* or *Cythere*, being enclosed in a bivalve shell, in which the front of the head, with the antennæ, is greatly developed, equalling in bulk all the rest of the body. The single eye has become two, which are very large, and attached to the outer arms of two bent processes, like the letters U U, which are seen within the thorax (Fig. 41, c).

"In this stage the little animal searches about for some suitable spot for permanent residence—a ship's bottom, a piece of floating timber, the back of a Whale or Turtle, or the solid rock. When its selection is made, the two antennæ, which project from the shell, pour out a glutinous gum or cement, which hardens in water and firmly attaches them. Henceforth the animal is a fixture, glued by the front of the head to its support. Another moult now takes place; the bivalve shell is thrown off, with the great eyes and their U-like processes, and the little Cirriped is seen in its true form. It is now in effect a Stomapod Crustacean, attached by its antennæ, the head greatly lengthened (in *Lepas*, &c.), the carapace composed of several pieces or valves, the legs modified into cirri, and made to execute their grasping movement backwards instead of forwards, and the whole abdomen obliterated, or reduced to an inconspicuous rudiment."—(Gosse: "Manual Marine Zoology.")

Professor Rymer Jones observes that the food of the Cirripedia consists of various small animals, and nothing can be more effective or beautiful than the manner in which it obtains its prey. "Its food is caught in the water around them by a mechanism at once simple and elegant. Any one who watches the movements of a living Cirriped will at once see that its arms, with their appended *cirri*,

* Latin, *balanus*, an acorn. † Greek, *lepas*, a limpet.

are in perpetual movement, being alternately thrown out and retracted with great rapidity; and that, when fully expanded, the plumose and flexible stems form an exquisitely beautiful apparatus, admirably adapted to entangle any nutritious atoms or minute living creatures that may happen to be present in the circumscribed space over which this singular casting-net is thrown, and drag them down into the vicinity of the mouth, where, being seized by the jaws, they are crushed and prepared for digestion. No sense but that of touch is required for the success of this singular mode of fishing; and the delicacy with which the tentacles perceive the slightest contact of a foreign body shows that they are eminently sensible to tactile impressions."

The process of exuviation common to the class Crustacea cannot take place with the shell in the CIRRIPEDIA, but the delicate skin of the articulated *Cirri* (whence their name "Curl-footed"), the tunic lining the sac, and the integuments of the whole body are regularly moulted. All the Cirripedia grow rapidly; and Darwin says, "in accordance with this rapid growth is the frequency of periods of exuviation. Mr. Thompson kept twenty specimens of *Balanus balanoides* alive, and on the twelfth day he found the twenty-first cast-off integument, showing that all had moulted once, and one individual twice within the period. This frequency of exuviation explains the astonishing masses of exuvia which Mr. Peach assures me he annually has observed off the coast of Cornwall; they are most abundant in April and May, but he has seen quantities also in September. He could easily, he tells me, have filled several quart-measures with them."

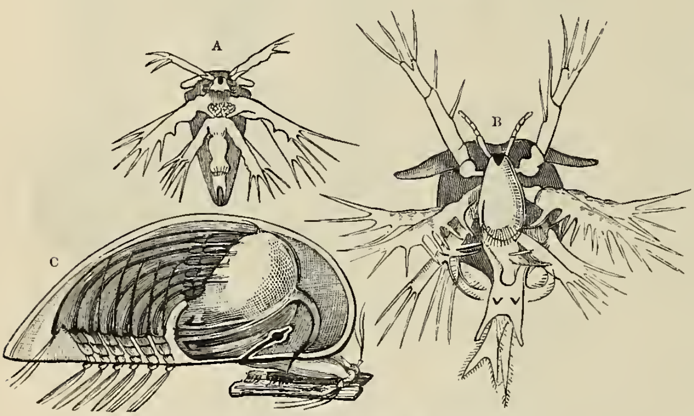


Fig. 41.—LARVAL FORMS OF CIRRIPEDIA.
A, Nauplius of *Balanus*; B, Larva of *Chthamalus stellatus*; C, Larva of *Lepas australis*.

The only difference of the growth of the shell in the Cirripeds and that of other Crustaceans is the new layers of thin shell which grow up or are deposited over the internal surface of the valves, the old shell adhering to the outside of the new one; the margins are added to slowly, but not continuously, instead of being formed at a single period.

"In the genus *Alcippe*, the whole of the external membranes are moulted, excepting the surface of attachment; but these Cirripeds live in cavities, which they form for themselves, and are thus protected."

"The most remarkable fact concerning the *peduncle* of *Lithotrya* is that the outer tunic, together with the calcareous scales with which it is covered, is moulted at each successive period of exuviation and growth. I demonstrated this fact in *L. dorsalis* and *L. truncata*, by removing the old tunic, and finding a new membrane with perfect calcified scales beneath; and as these two species are at the opposite extremes of the genus, no doubt this fact is common to the whole genus. I know of no other instance amongst Cirripedia in which *calcified* valves or scales are moulted. I am not certain that the whole skin of the peduncle is thrown off in a single piece, though it is almost certain in the case of the uppermost and lowest portions."

In viewing *Lepas* in comparison with other forms, it is necessary to treat it as attached by its head, its thoracic appendages serving as cirri, its abdominal segments being suppressed or undeveloped.

The Cirripedia extend over the whole world, and all the species are marine; some are parasitic on Whales, others on the Turtle, and many forms live floating about on ships and timber.

HENRY WOODWARD.

CONCLUDING REMARKS.

We have thus arrived at the conclusion of a necessarily very condensed sketch of the vast group of animals arranged by naturalists in the great division of the Arthropoda, a group which is certainly the most numerous in species, and probably also in individuals, of all the great primary sections into which the animal kingdom may be divided. A few additional words summing up the relations of the group as a whole may not, however, be out of place.

A consideration of the habits of the species and their relations to the world at large seems to indicate that the primary function of the group in general is that of a natural police, acting sometimes openly in the sight of all, sometimes in a concealed fashion, which renders it difficult to realise the extent of their influence. Among the scavengers both of land and water the foremost place must certainly be assigned to Arthropods, numbers of which seem to be constantly on the watch for all those articles called by the French "immondices," the continued presence of which, either in the air or in the water, cannot fail to be either offensive or injurious to other living organisms. Excrementitious matters and putrefying or decaying animal and vegetable substances are thus rapidly got rid of and brought once more into the cycle of vitality, and in these useful operations thousands of species of insects of different orders, many mites, and a very large proportion of the class Crustacea, are perpetually engaged.

Of the rest, while there are some which seem to have no particular mission, the great majority may be regarded as acting more or less powerfully as checks upon the increase of other animals and plants, and this often in so direct a manner that our best examples of the system by which the numerical proportions of different kinds of organisms are maintained in the world are to be derived from the study of these creatures. The whole series of predaceous insects, the carnivorous Myriopods, and the great mass of the Arachnida, are most efficient agents in keeping down the development of their weaker fellows, while a host of plant-eating species, especially of insects, perform the same part for the vegetable kingdom. Parasitism, which is common throughout the three great classes of Arthropoda, and manifests itself in many very remarkable ways, plays a most important part in checking the increase of animals of many kinds, and, as we have seen, provides a peculiarly delicate means of regulation, seeing that under the influence of parasites the creature affected is able to perform its principal functions in the economy of nature, but is weakened or altogether destroyed when the time of reproduction arrives.

The action of the Arthropods in nature is in numerous cases greatly intensified by the important changes through which so many of them pass in the course of their life-history. Phenomena of more or less similar character certainly occur in other groups, but those extra-ovular changes which we dignify by the title of metamorphoses, and which in their extreme manifestations make one animal play the part of two, constitute a general characteristic of the Arthropoda, and have a most important bearing on their life-history. Of the metamorphosis we may distinguish two kinds in the Arthropoda generally. In the great majority of the types distinguishable in the group, we find what may be called a "direct" metamorphosis, that is to say, the young animal escapes from the egg in a form differing more or less from that of its parents, but destined to reach the mature form by simple growth and development of its parts with or without the addition of new parts as it advances in age, a mode of development which we recognise throughout the Crustacea, Arachnida, and Myriopoda, and in the whole of the lower (or hemimetabolous and ametabolous) insects. In the metabolous insects, or insects with a complete metamorphosis, we find another set of phenomena superadded, a more or less worm-like larva-stage being intercalated between the egg and the perfect insect. The explanation of this seems to be furnished by the life-history of certain parasitic forms of Coleoptera, such as the Meloïdæ and Stylopidæ, in which the insect when first hatched is a little six-legged creature presenting all the external characters of a larva destined to undergo direct development towards the perfect form, but subsequently giving origin to a soft, maggot-like larva, which would never be supposed to have any connection with its predecessor. It seems probable that, in the history of the class Insecta, a similar change, the traces of which are now preserved only in a few species, may have taken place in the course of development of certain forms, and that through these the whole series of insects with a complete metamorphosis may have

originated from hemimetabolous ancestors. However it was introduced into the life-history of the Insecta, this worm-like larval form is certainly their most important modification. As already indicated, it enables each individual to play two distinct parts in the economy of nature, and it is by its introduction alone that the internal parasitism, which is characteristic of so many families of insects, is rendered possible.

In some few insects, but much more strikingly in members of the classes Arachnida and Crustacea, parasitism superinduces a metamorphosis of another kind, which is commonly known as "retrograde metamorphosis," seeing that the adult parasite, instead of showing an advance upon the structure of the newly-hatched young, exhibits a marked degradation of type. This curious and interesting phenomenon is well shown in the numerous forms of parasitic Crustacea, such as the Lerneadæ and Rhizocephala, and especially in such parasitic Isopods as *Entoniscus*, &c., the larvæ and males of which display true Crustacean characters, while the parasitic females are mere egg-sacs, which might very justifiably be taken for worms. The Cirripedia again exhibit another phase of what must be termed retrograde metamorphosis.

It will be seen, from the foregoing rapid sketch of the development of the Arthropoda, as also from various statements contained in the preceding description of the classes and orders composing the group, that whatever indications of alliances outside the group are presented by its members are all in the direction of animals now included under the great division of the Vermes. In the general description of the characters of the class Insecta, we took occasion to indicate that in former days the Arthropoda and Vermes, as then understood, were regarded as forming a single great division of the animal kingdom, the Annulosa, characterised by the ringed or segmented structure of the body displayed by its typical members, and we must confess to a lingering doubt whether such a grouping does not present a more philosophical idea of the relationships of these creatures than the one now generally adopted. Under any circumstances, it is among the Vermes that we must seek the nearest allies of the Arthropoda; or, in other words, to adopt the views of the illustrious Darwin, which, whether accepted as the expression of facts or not, must, as we have more than once stated, furnish the guiding principles in inquiries of this nature, the ancestors from which they were derived.

It would seem, from the investigations of Mr. Moseley and others upon the curious genus *Peripatus*, that the remarkable worm-like creatures forming it, which are so peculiar both in their organisation and in their geographical distribution, represent the surviving progeny of organisms directly uniting the Annelida (the highest class of Vermes) with the Myriopoda as we now know them. If this be the case, one line of descent is very plain. The group of Chilognathous Myriopods (such as *Julus*, &c.) would be easily derived from modified *Peripati*, and the transition from them to the Chilopoda presents no difficulties, even from the consideration of existing forms. The production of Myriopods must have taken place at a very early period of the world's geological history, as their remains have been detected in Devonian rocks in America. The production of six-legged larvæ by the Juliform Myriopods, if not inherited from the Peripatoid ancestor, may have been superinduced as a saving of material in the egg, and these larval forms lead directly to the truly ametabolous Thysanura, among which *Campodea* is regarded by Sir John Lubbock as approximately representing the lowest and earliest type of true insect, from which all the other multitudinous forms may have been derived by descent with modification, the Hemimetabola retaining the direct mode of metamorphosis as above described, starting from the *Campodea*-like larva and reaching the adult form by growth with addition of parts; the Metabola proceeding from the latter by the superaddition of a vermiform larva stage with its concomitant or resting pupa stages. In most cases the primitive larval form appears to have become suppressed in the metabolous insects, although it is still retained, as above mentioned, in *Meloë*, *Sitaris*, *Stylops*, and their allies.

With regard to the Crustacea and Arachnida, we get no information from this assumed line of descent, and the fact that the latter belong to the tracheate series of Arthropods renders the question of their origin rather puzzling. It would appear, however, that the primitive larval form of the Crustacea is the little creature described as a *Nauplius* (pp. 194-6), which is the first product of the egg in the majority of the lower types of the class, while in the highest groups the young animal is generally of the form originally described as a distinct genus under the name of *Zoëa* (pp. 194-6).

For a long time it was supposed that this constituted a positive distinction between the lower and higher Crustacea (some intermediate forms, Edriophthalmia, showing no larval forms at all), but the researches of Fritz Müller proved that in certain Shrimps (*Penæus*, pp. 194-6) the *Zoëa*-form was preceded by a *Nauplius*-form, thus furnishing analogous evidence to that existing in the case of insects, of the existence among Crustacea of a primitive and a superadded larva (*Nauplius* and *Zoëa*), of which the former had in many cases become suppressed.

If we consider the Crustacea to follow the same principle in their development as the Insecta, we must regard the *Nauplius*, or some Naupliform creature, as the primitive form of the class from which all the rest have procceded by descent with continual additions and modifications of parts; but it is hardly possible with our present knowledge to indicate the particular type of the Vermes from which, or from the larva of which, the primitive *Nauplius* could have originated. But the interesting fact becomes perfectly plain that as the *Peripatus* could have nothing to do with the origin of the Crustacea, the evolution of the Arthropod type must have taken place along, at least, two lines of descent of different origins, a view which has been adopted by Prof. Balfour in his very valuable work on "Comparative Embryology." It is possible that the starting-point of the Crustacean line was from some organism pertaining or approximating to the group of creatures now known as Rotifera.

The Arachnida, through the curious little Tardigrada, which are generally considered to have Rotatorian affinities, may have originated from the same point as the Crustacea, but if so they must have diverged at an exceedingly early stage of the evolution and formed a branch of their own, gradually acquiring those characters which bring them apparently into affinity with the Insects and Myriopods. The character of the respiratory organs, which has been adopted for the division of the Arthropoda into two main groups of Tracheata and Crustacea is evidently of no consequence in connection with this question of descent, seeing that it is quite clear, from the analogy of *Peripatus* and the Earth Worms, that throughout the Annulosa the principle on which the originally aquatic forms are adapted for aërial respiration consists in the substitution for the primitively exposed branchial organs of concealed cavitary organs, the arrangements by which the blood is brought in contact with the respiratory medium being strictly homologous in both cases. The passage upward through the Mites to the Spiders and Scorpions may then easily be conceived. The parasitic forms, such as the Linguatulina, originated by a process of retrograde metamorphosis; while the singular group of the Pantopoda, with their remarkable larvæ, would seem to have remained from an early period at a very low stage of development.*

Another group, which we have here placed with the Crustacea, is regarded by some naturalists as belonging truly to the Arachnida. This is the order Xiphosura, including of living forms only the few species of King Crabs or Horseshoe Crabs, the structural relations of which to the Scorpions would seem to be very close, and certainly raise a difficult problem, and one which is rendered still more interesting by the fact that, according to the researches of Dr. Jules Barrois, a Limuloid or King Crab-like stage occurs in the development within the egg of certain true Spiders. For the present this and many other such questions must, however, remain open. In all biological problems relating to the past developmental history of the organic world we must for a long time yet expect to come continually upon obscure and puzzling points, which only a more extended knowledge of minute details can clear up.

* Professor Balfour (Comp. Embryol., vol. i., p. 448) says of the Pycnogonida :—"The six-legged larva has none of the characteristic features of the Nauplius, except the possession of the same number of appendages ; " but he places the group among those of doubtful affinities.

W. S. Dallas.
Henry Woodward.

GRAND DIVISION, OR TYPE.—VERMES (THE WORMS).

CHAPTER 1.

THE RINGED WORMS.

The Various Sorts and Conditions of Worms—Characters—Classification—ANNELIDA, *THE RINGED WORMS*—OLIGOCHÆTA—The Earth Worm—Characters—Structural Peculiarities—Habits—Other Species—The Naidæ—The Tubificidæ—POLYCHÆTA—Marine Worms—Characters—ERRANTIA—APHRIODITIDÆ—Sea Mice—Scale Backs—The Eunicidæ—The Sao—Habits—The Nereidæ—The White-rag Worm—The Syllidæ—The Phyllodocidæ—THE TUBE-MAKERS—Characters—The Lug Worm—Habits—"Baiters" on the Search—CIRRATULIDÆ—Characters—The Terebellidæ—Their Larvæ—The Serpulidæ—The Fan Sabella—Serpula Vermicularis—Its Array of Hooks—The Protulæ and other Tube-makers—THE LEECHES—Appearance—Action of Sucker—Characters—Different Kinds—The Horse Leech—The Glutton Aulostoma.

THE commonly received opinion about Worms is, that they are very unimportant animals which lead very obscure lives, and that there are not many of them. But a little observation proves the fallacy of the greater part of the popular idea. The common Earth Worm is seen in numbers early in the morning, and on every lawn the birds may be noticed pulling them out of their holes and swallowing them. Boys who require Worms for fish-bait soon become impressed with their numbers, for every dig of the spade brings up one or more. By the sea-side, Lob Worms are forked out of the sand by fishermen, in abundance. In chemists' shops one used to see quantities of leeches in pots, and that they are Worms is pretty evident. Sometimes in out-of-the-way localities, the shop-windows of worm-doctors are to be seen filled with bottles containing flat, long, limp-looking things, called Tape Worms; and every nurse knows that children suffer from Thread Worms. The farmer loses his sheep from a curious head affection, and on examining them he finds peculiar Worms. Grouse and Chickens die from the gapes, and it is a Worm that does it. Pigs suffer from a Worm in their muscles, and fishes have others in their bodies and eyes, and man has them sometimes in his blood. Finally, in the marine aquarium the loveliest fan-shaped expansions, coming out of tubes fixed to the rock, are the breathing organs of a Worm. In numbers, probably the Worms surpass all other things except the Infusoria; in habits they are most varied, and they are correspondingly diversely fashioned. In some Worms there is boldness and a power of roaming for purposes of attack, and then they are well provided with structures and organs; but in others there is only a very passive existence, and there is an extraordinary absence of structures, senses, and of many organs. Parasitism within animals is the lot of many Worms, and some lead a part of their life in one animal, and another in a second unwilling host, or they may live free at some time or other. So varied are the shapes and so inconstant are many of the structures of the Worms, that it is by no means easy to give a definition which shall include them all. Not only peculiar structures, but also the absence of certain structures known to exist in other animals, have to be considered. Thus it is found that an animal does not exactly correspond with one of the articulate groups; and another resembles in certain points, but not in all, an Infusorian. They are then placed with the Vermes, because of the existence of certain fundamental structures. Again, many of the Vermes are parasitic, and their structures have been most curiously modified to meet their method of life—or, rather, their methods—for most pass through very remarkable life-cycles.

The Vermes do not move by means of articulated limbs, and the body is not jointed like that of a Crustacean or Insect. But whatever may be the shape of the body, it is composed of incomplete segments, the majority of which are similar, and is more or less ringed outside. The segments are provided with offensive and locomotive organs on both sides, and usually with a special excretory organ opening from within. There is a water system communicating with a cavity in the body surrounding the digestive system, and with the outside, called the perivisceral cavity. The digestive system may be well developed, but in some parasites it is absent, and their nutrition takes place by absorption through the outside of the body. There is a kind of circulatory system present in some, and also special organs of respiration, such as branchial tufts; but many are without them. The nervous system may consist of a cord around the œsophagus, with ganglia above and below, and a ganglionic cord along the ventral surface within; or the vestiges of the system may be very scanty. Sense organs, such as eyes, may exist in a rudimentary condition, and also organs of feeling. The digestive organs vary greatly in their development; and the stomach and intestines, fairly developed in some, are wanting in others. The movements of the body are not produced by jointed

limbs, but by the segments, assisted or not by lateral projections and cilia. Although there is great diversity in form, the organs and structures of the body are, to a great extent, the same on both sides, and hence there is bilateral symmetry.

The Vermes are divided into five classes—the Annelida, the Gephyrea, the Rotifera, the Nemathelmintha, and the Plathelmintha—or the True-ringed Worms, the Marine Worms, the Wheel Animalcules, the Ribbon Worms, and the Flat Worms.

CLASS ANNELIDA (THE RINGED WORMS).

SUB-CLASS CHÆTOPODA.

These Worms have bristles upon the segments, either on processes called false feet (parapodia), or in depressions in the tissues of the skin. Presenting great differences in structure, they are divided into two great orders, in one of which (the Oligochæta) the bristles are comparatively few, and never on parapodia: there are no tentacles, cirri, or branchiæ, and the sexes are combined; these Worms, moreover, do not undergo metamorphosis. The second order (the Polychæta) are Marine Worms, with separate sexes, undergoing metamorphosis, and they have numerous bristles carried on parapodia, and also tentacles, cirri, and branchiæ.

ORDER OLIGOCHÆTA.

These are long Worms found in earth, mud, and fresh water, which are known by their negative, rather than by their positive zoological characters. They have no structures on the sides which may be called "feet," and they have not any armature like jaws, in relation to the pharynx. They are without tentacles, and do not possess cirri or branchiæ. The sexes are combined, and there is no metamorphosis. Being Annelida, they have segments, and there are bristles projecting from them. There are two sub-orders of these sparely-bristled Worms, and in the first (the Terrestrial, or Oligochæta terricola) the Earth Worm is the type.

THE EARTH WORM.

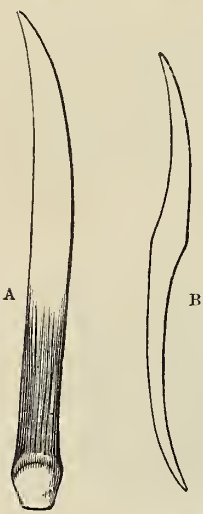
The Earth Worm, or Dew Worm,* is such a familiar object that it is only necessary to remark on some of its peculiarities. The head is a long, obtuse cone; the first segment is usually lobe-like; it overhangs the wide circular mouth, and is more or less retractile within the second ring. The segments of the body are narrow, and furnished with minute bristles, some of which, more or less hooked, are called spinets, and are retractile. There are no eyes, jaws, or branchiæ. On the segment behind the first are two furrows, often joined by a cross one; and farther back is a smooth, glistening brown part, differing from the rest of the Worm in appearance: it is called the clitellus. The hinder part of the body is flatter and broadens out, and the anal segment is small, reddish, and has tumid projections. The genital pores are on the fifteenth ring. There may be from twenty-eight to thirty-two rings in front of the clitellus, which has six segments, and 106 behind it. In the skin and clitellus are organs for producing mucus, and it can be noticed that a red fluid circulates in an imperfect circulating vessel called the pseudo-hæmal system. The nervous system consists of central ganglia above the pharynx, cords connecting them around the pharynx with a long chain of nerves and ganglia, extending through the length of the body on the ventral wall of that cavity which environs the internal organs—the perivisceral.

The upper lip is slightly elongate, and covers the mouth, which leads to a muscular pharynx, ending within the body, at about the seventh segment; a narrow œsophagus is continued backwards to about the sixteenth. There are three pairs of pouches in the sides of the œsophagus, which contain

* *Lumbricus terrestris.*

a calcareous matter. This gullet widens into a sort of crop, which terminates in a thick and muscular gizzard. Then follows a single tube—the intestine—which is turned in, as it were, along its back, so that there is a longitudinal projection into the intestinal canal. The excretory or segmental organs are tubes which are much convoluted, and one is situated on each side of every segment except the first. Externally, it opens by a minute pore placed close to a pair of bristles or setæ; and internally it communicates with the perivisceral cavity by a wide, funnel-shaped ciliated aperture.

Each segment of the body has four double rows of minute setæ on it, which project slightly beyond the integument, and pass inwards into the tissues. A series of small apertures, or pores, one for each segment except the first, is on the back, in the median line, and they lead inwards to the perivisceral cavity; and upon the opposite side of the body are eight apertures for the reproductive organs. When an Earth Worm is in good health and clean, its thin, transparent, but dense outside skin shows a play of colours. Within this layer is a connective tissue with the meshes filled with a gelatinous substance, and still within is a thick layer of circular muscular bands, with pigment granules. A longitudinal layer of muscular fibres is internal to all the rest. So the outside of the Worm is muscular and membraneous, and contains many cells for the secretion of mucus outside, and passages into the inside. Within are the viscera and the perivisceral cavity, and this is subdivided by a tissue which passes inwards from the divisions between each pair of segments. Yet there is communication between each subdivision, and also between it and the outside, through the segmental organs. The short spinets, or curved setæ, project farther into the interior of the body than externally. The ends of each pair are close, but their origins within the body are wider apart; each is enclosed in a sac in which it is developed, and to which the muscles by which it is protruded are attached. There are eight setæ to a segment; one pair is not far from the middle line below, and the other pair are farther out on either side.



SPINE (A) AND SPINET (B) OF LUMBRICUS TERRESTRIS.

There is a colourless fluid with corpuscles in the perivisceral cavity, and the deep-red fluid already mentioned is found in a system of pseudo-hæmal vessels. These are longitudinal and transverse canals and branches, ramifying in all parts of the body except the outside skin. In the seven front segments the longitudinal vessels form a network, and behind it cross vessels are greatly developed, and form five to eight pairs of false hearts. They contract from the back towards the under side.

The Earth Worm is very widely distributed; and some of the species, for there are many, are found on continental and oceanic islands, yet they neither swim nor like salt. They are all nocturnal in their habits, and swallow earth, and digest any organic matters which may be in it, casting forth the residue in the form of cylindrical twists of sand or mud. Charles Darwin has shown that they are the great producers of good soil, and hence the term vegetable mould should rather be animal or worm mould. The Worm should therefore be cultivated rather than destroyed, and the only harm it can do is when it lives in the same pot as a flower, for then it abstracts the organic part of the mould which would be of use to the vegetable. Formerly Worms were much used in medicine. The Earth Worm lays its eggs in capsules at some depth in the soil during the spring, and they hatch in the summer, and the young are about an inch in length, and have no clitellus. Like many other Vermes, the Earth Worm has the power of reproducing lost parts, and of healing and growing when cut in half. Anglers use the common Earth Worm for Eels and Perch, but another species, the Brandling (*Lumbricus fœtidus*), is the best for Trout. This is a reddish-brown Worm with alternate yellow and brown segments, and it has a tapering tail, and exudes a yellow pungent fluid when touched. A huge Worm occurs in Ceylon, called *Megascolex cœruleus*, and it is sometimes forty inches long, and is as thick as a finger. Its segments are surrounded by a complete circle of setæ. Dr. Baird described a species of this genus which had been found in a hot-bed in a garden in Wales, but probably it had been introduced accidentally.

There are many species of Lumbricus in England. In one, the front of the body is different

from the hinder part, *L. anatomicus;* one is greenish, and is found under stones in cattle fields, *L. viridis;* another is phosphorescent, and there is a pigmy form of the great Earth Worm.

The second sub-order is that of the water and mud inhabiting Oligochæta—the Oligochæta limicola. There are four families of them, and that of the Naidæ is the most important, *Nais proboscidea* being the type. These Naidæ have a head distinct from the body, and the first three or four segments have no bristles. The mouth is exactly terminal, and there is no overhanging lip as in the Earth Worm. Their body is much flattened, and the bristles are comparatively long, and there are two kinds of them on the segments, which are rather indistinct. The upper bristles are setæ, and are collected in small bundles, and the lower are spinets, which are forked at the tip; and with their aid the Worms creep actively, and even swim. They live on small animals and are oviparous. They are remarkable for their facility of multiplying by spontaneous division. This has been noticed in the typical species, whose individuals are about half an inch long, and are found about the roots of aquatic plants. Mr. Lewis noticed that the perfect Worm begins to grow a second head near the extremity of the body, and then other segments are developed, the tail, or final segment, being the identical tail of the mother, but pushed forward by the young segments, and now belonging to the child, and only vicariously to the mother. In this state, he adds, we have two Worms and one tail. In some other species the tail has finger-shaped processes which probably act as respiratory organs. One genus, Aulophorus, secretes a tube, which it carries about, and its upper bristles are hair-like, and the lower ones stiff. Some Naidæ have eyes, as in the instance of the type, but one species, which has finger-shaped projections (*Protodigitata*), has not any. The genus Chætogaster has a cylindrical body, truncated in front, without eyes; and the mouth, which is terminal, is barbed underneath on the first segment. The bristles are in a single row on either side of the ventral aspect, but they are massed together in groups of four or five or more hooked setæ. They reproduce principally by a process of gemmation or budding, and form chains of four, eight, or sixteen individuals, and each has four segments including the head.

The genus Lumbriculus, which has a contractile vascular space to each segment, and no vascular network in the skin, has species living in fresh water, which are red or brown in colour, and have no clitellum.

The family Enchytræidæ may be typified by a Scottish species (*E. vermicularis*). This is a white, indistinctly segmented Worm, with the thirty to seventy segments armed with short spinets in four small fascicles or bundles. It lives in the soil under the bark of rotted trees or decaying leaves. There is a small white spot near the first third of the body. If this little Worm, which is found lying rolled up in a loose, spiral manner, be placed on one's hand, it wriggles much and soon dies. It cannot live except in moist places.

The family Tubificidæ contains numerous genera, with four rows of recurved setæ, which may be simple or forked, and the species have contractile vascular canals, besides the dorsal vessel. The reproductive organs are in the 9—11 segments. These Worms* live in water in cylindrical tubes of mud on the bottoms of streams, and their mouth segments are united, and often lengthened, and their skin is transparent and appears of a deep red colour in the water; the portion within the erect tube is pale straw colour. The dorsal vessel is distinctly seen beneath the skin, and the intestine also, which makes a twist at every segment. They are common in the mud of the Thames. This little Worm is gregarious, and when seen in clear water their movements, each half out of its tube, are interesting. They withdraw into their tubes on alarm, and do not come out again for some time. It is the tail end that projects and not the head. One of these red Worms lives in wet gravel, or sand, or brackish water;† and a very filiform species, which has a clitellus, lives between tide-marks;‡ and another lives as a parasite in the Mussel.

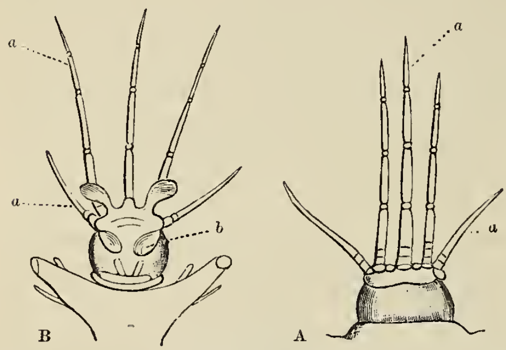
ORDER POLYCHÆTA.

These are highly-developed Marine Worms, and they have parapodia, or feet, on their sides, furnished with numerous bristles, as their name implies. They have also tentacles, cirri, and branchiæ. The young are not born like the parent, and undergo a metamorphosis. The sexes are usually separate. The Polychæta are divided into two sub-orders. Firstly, those which possess

* *Tubifex rivulorum.* † *Tubifex lineata.* ‡ *Clitellio arenarius.*

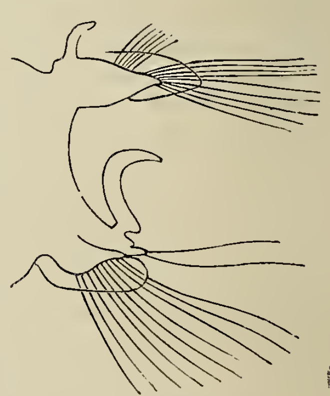
well-developed foot organs, which lead a roaming life, the exceptions being very few, and which are carnivorous and predaceous. They are the Errantia. Secondly, those which live in protecting tubular structures, and which have feebly developed feet, and are called the Tubicola.

In examining these many-bristled Worms it is advisable to employ certain descriptive terms. Thus, the first segment of the body is called the prostomium, and the mouth opens on it: the second is the peristomium. When the three front segments are united, or when they differ from those which come after, they are called the head or cephalic segments; but when this is not the case the Worm is said to be acephalous. The head has various appendages according to the genera. Antennæ are soft filaments varying in number from one to five, and they arise directly from the head, are not retractile, and are usually jointed at the base. Sometimes palpi exist, and they are soft, entire, or jointed processes, arising from the sides of the mouth. The tentacles are soft, bristly, or thread-shaped, non-retractile processes, which arise from each side of the segments of the head in pairs, and spread laterally. They are often very long, and are contractile in the acephalous genera.



NORTHIA TUBICOLA.
A, cephalic segment; B, mouth, &c.; *a*, tentacular cirri: *b*, upper lip.

The mouth is underneath the head, and is a round or transverse opening to the gullet. It has usually a plain margin. In the acephalous genera it is terminal, and has external tentacles, but there are no jaws, and in the cephalous it is nearly terminal and looks forward horizontally. It is almost always furnished with a proboscis in the cephalous tribes; that is to say, the œsophagus or gullet can be protruded. It consists of two segments, and can be put forth at pleasure by a process of turning inside out. It is often armed with horny jaws, in opposite pairs, or is roughened on the surface with horny prickles; or it may be covered with pimples, or be plain. The head is succeeded by the "thoracic segments," and in the cephalous genera there is but one of them. It is naked and has no appendages. But in the acephalous genera, and in some of the others, the thoracic segments are distinguished by peculiarities in their structures and appendages. They may be fleshy, and contain most important organs, and the branchiæ are often limited to them. The abdominal segments complete the body, vary in number, are alike, and lessen in size, the last being the anal. This has no setigerous feet, and no soft appendages; but more commonly a pair of soft filaments, called styles, project behind. The vent is terminal and central. The segments have appendages on either side, and the principal is a lobe, which is called the foot, or parapodium.


FOOT OF NEPHTHYS.

The so-called foot, or parapodium, is a pimple-shaped projection on either side of a segment. It supports the bristles, which are, as it were, sheathed by it, and it is a basis of attachment for the branchiæ, and soft, setaceous filaments, called cirri, resembling tentacles. The foot may be in one lobe, or there may be two lobes; one, upper or dorsal; and the other, lower or ventral. These lobes, also called branches, are more or less apart, and when there is but one branch, or lobe, the foot is said to be uniramous, and when there are two, biramous. Taking the biramous foot of one side of a segment of *Nepthys longisetosa* as an example, the upper and ventral lobes are seen to be wide apart, but to be connected. The bristles of the two lobes are long hair-like setæ; the cirri are two curved hooklets projecting downwards from each lobe, and besides these there is a kind of flap behind the bristles, which probably is a rudimentary branchia. The bristles are of four kinds in these Polychæta, the spine, which is subulate, straight and tapering from the base to the apex. It is placed in the midst of a bundle of bristles. The spinet is a hook or fork, and is only found in a few

genera. The bristles are either formed of one continuous piece or are jointed. They may be hair-like, setaceous, or slender, and tapering insensibly to the end, lanceolate or swollen. The branchiæ in the cephalous Worms are attached to the base of the foot, on the upper or dorsal side, and are either restricted to a certain number of segments, or they are found on all. They are either aborescent, combed on one side, flat, and veined, or they may be filamentary. At the base of the branchiæ, or in portions of the lateral trunks, are "hearts," the direction of the fluid being from behind forwards in the dorsal vessel, and the opposite in the ventral trunk. There are numerous branches to the trunks in most, but not in all, the Polychæta. No segmental organs—excretory—have been discovered in the majority of these Worms, but they do exist in some, as short ciliated canals opening on the parapodia or ventral surface, or as cavities with glandular walls. They may excrete a renal deposit, or may have to do with reproduction. The nervous system consists of a chain of ganglia, one pair for each segment, connected together by longitudinal and transverse bands which diverge below the cerebral ganglions and the succeeding pair, to allow of the passage of the œsophagus. The commissural bands differ in length in the many genera, and some fusion of the ganglia also occurs. An extensive series of nerves is given off to the viscera.

The general cavity of the body, the perivisceral, contains a fluid and colourless corpuscles, except in two genera; and this fluid is continuous with that of the parapodia, and their accessory structures, they being more or less hollow, and in relation to the perivisceral cavity. Cilia, and the movements of the body, produce the circulation of this fluid. Branchiæ are represented by ciliated spots on the dorsal side of the bases of the parapodia, or ciliated tubercles may arise from the spot, and it is within them that the cæca of the alimentary canal terminate. There may be filiform branchiæ or there may be branchial tufts. The pseudo-hæmal system may or may not be present, and when it is found, as, for instance, in the genera where tufted branchiæ exist, loops of the great vascular trunks enter them. These trunks are dorsal and ventral, connected by transverse branches, and may be rhythmically contractile. They are large, squamous, lobe-like, or tubercular. In many acephalous genera the branchiæ are placed in front, in tufts.

The cirri are simple, soft, tapered filaments, or papillary processes attached to the dorsal and ventral lobes, at or near the base. Their office appears to be tactile, and they may be considered as the tentacles of the body.

In the Polychæta the foot and its accessory structures are well developed on either side of certain segments. The group, as a rule, are cephalous, and their alimentary canal is almost always of the same length as the body, and extends without marked distinction into stomach, and convoluted intestine, from the mouth to the anus. In some genera, long cæca are given off from each side of the alimentary canal, and are sometimes much convoluted. The pharynx is muscular, and when turned out as a proboscis is in some instances as long as the body. There are papillæ on it, and, in some cases, horny teeth, which are carried and implanted in the muscular tissue. Eyes and auditory vesicles exist; the former are simple expansions of nerve imbedded in pigment, and are usually on the prestomial segment; but in some genera they are on the segments and tentacles. Some species have them on the tail end, and the locomotion is then with the posterior part forwards. Otoliths have not been satisfactorily made out in the Errantia, but they have been discovered in the Lob Worm.

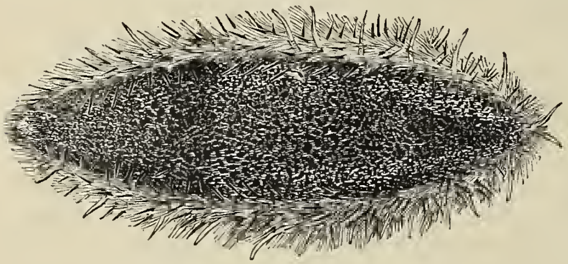
SUB-ORDER ERRANTIA.

The majority of these many-bristled Worms lead an active, predatory life; have a distinct head, carrying eyes, tentacles, and usually tentacular cirri. The body is not divided into different regions, and the highly-developed parapodia are used as oars. The gullet is prosbosciform and armed, and when the branchiæ exist, they are tufts or comb-shaped projections on the dorsal lobes of the feet. They swim freely, and only a few inhabit temporarily very thin membraneous tubes. In some genera there are flap-shaped processes to the body, which are called elytra and flap-shaped branchiæ.

The Errantia are very numerous in individuals. There is a host of genera, and no less than twelve families, some of which are again subdivided.

THE FAMILY APHRODITIDÆ.

Of this family the very un-worm-like animal called the Sea Mouse,* with long bristles on its feet, which gives all the colours of the rainbow in the sunlight, and is common on the south coast of England, is a good example. It frequently attains the length of from eight to ten inches, and is of an oval shape. Its back is covered with numerous scales, or elytra, hidden under a covering of fine bristles. Another, called the Porcupine Sea Mouse,† has the scales visible, ranged in double series on the back. It is not so long as the Sea Mouse, nor is it as brilliant in the iridescence of its foot setæ. Found on our coasts, it, like its fellow, affords food for fish. The rough Scale-back ‡ is one of the family, and is smaller than the species just noticed. It is of a brown colour, and underneath it is whitish. The back has twelve pairs of scales, which overlap in the middle line, and are hairy on the free edges. The Worm is thus covered with armour above, and the head is protected by the first pair. There are four small black eyes, three feelers, with knob at the end, and two palpi. The animal has twenty-five pairs of feet, and the setæ of their dorsal and ventral lobes are golden yellow. There are 7,230 setæ of exquisite structure, according to Dr. Baird, on the animal. Most of those scaled Worms move at a slow pace, but they can swim pretty quickly. The proboscis is long and strong, and has filaments around the opening, and it leads to a short digestive apparatus. The species of Lepidonotus have horny curved jaws, and are carnivorous like the others. They live on living Invertebrata, and are cannibals also, and like most of the family frequent the region below low spring tides, and even live under stones on rocky shores at a less depth. Some live deeper, and a few burrow in the sand very easily. One of the species of Scale-back Worms is long and narrow, having seventy to one hundred and ten segments in the body. It has the scales, in pairs, forward, but the under part is naked, and the scales alternate, with dorsal cirri. This Scolopendrine Scale-back§ is four inches in length, and it frequently forms a tubular case of sand and pieces of shell for itself, which it agglutinates with a mucus secretion from its body.



THE SEA MOUSE (*Aphrodita aculeata*).

This species belongs to a sub-family of the Aproditidæ, and its congeners are found on the northern sea-coasts, the Australian, and Antarctic coasts, and in the Mediterranean Sea.

The Boa-shaped Sigalion|| is also a long narrow Worm with numerous pairs of elytra, which reach the end, and may amount to 140 pairs. The Worm is eight inches in length, and only a quarter of an inch in breadth. The feet are very numerous, and there are horny jaws. They live near low water-mark in the British and Mediterranean Seas.

Another family is that of the Amphinomidæ. They have no scales on the back, but an uninterrupted series of shrub-like branchiæ on each side of the body attached to nearly every segment. Most are found on the shores of warm and tropical countries, and the boatmen of Ascension Island wrongly consider the pricks of their setæ to be poisonous. The genus Euphrosyne, with an oval body made up of a few segments, which bear branchiæ in tufts, placed behind the feet, frequents the west and south of England, and lives down to about ten fathoms.

The family Eunicidæ is distinguished by a long and numerously segmented body, and a distinct and projecting head. The proboscis is short, and is furnished with several pairs of jaws placed one over the other, and approximated beneath, so as to rest on a kind of under lip of the same texture. The body is usually long and slender, and the number of tentacles varies. The first and second segments have no feet, and the others have feet which are one-lobed and carry dorsal and ventral cirri and comb-shaped filaments or branchiæ on the dorsal side. The genus Eunice has foreign species more than four feet in length, and one found on our coast is two feet long, and as thick as a man's finger, the body consisting of 300 segments.¶ It is of a dark green colour, and the

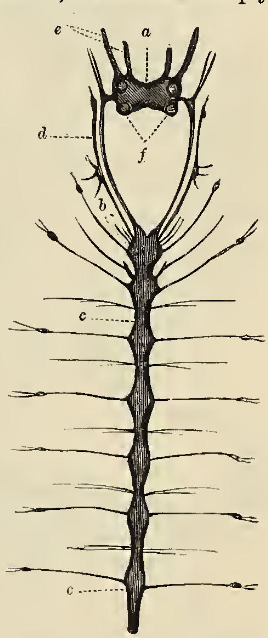
* *Aphrodita aculeata.* † *Aphrodita hystrix.* ‡ *Lepidonotus squamatus.*
§ *Polynoe scolopendrina.* || *Sigalion boa.* ¶ *Eunice sanguinea.*

branchiæ are intensely red. But the tints depend much on the situation where the Worm lives. When they are found in clefts of rocks, living in a kind of gallery which they construct, they are rich in their tints, and are iridescent. On the other hand, if they are taken amongst sea-weeds, or from off a muddy bottom, they are dull in colour.

The Sao,* one of this family, lives in a tube which it constructs for itself, and which presents the exact appearance of a quill pen. It is of a horny substance, about four inches long, smooth, transparent, and somewhat flexible. Living in soft mud, the animal immerses one end of this tube, and protrudes the other end to some distance. The habits of this Worm have been described with great accuracy by Dr. Johnston, whose words we quote :—

"One unceasing object of its life is the capture of prey. For this end it must protrude the anterior portion of the body beyond its tube, and raise itself above the surface of the mud, and remain in this position on watch. To enable the Worm to do this with ease is, I conjecture, the office of the forceps-like bristles of the feet; with their ends, it may hook itself to the rim of the tube, and thus obtain a support without the waste of muscular power. A long watch is thus rendered less irksome, while at the same time the capacity to seize upon a passing prey is increased. The prey caught, analogy leads us to conclude that the Worm will instantly retreat and sink within its tube, where it can feed without disturbance or fear. But as the entry and passages are narrow and unyielding, it seems to follow that the prey should be held by the mouth alone, when in the act of being dragged within the tube, and hence surely the reason that the mouth has been furnished with the hard tubercles to the lips; for when pulled together and put in contact, they must give a firmer grip and hold than could otherwise be taken. The use of the tube is to protect the body from the pressure of the soft mud in which it stands immersed. When the tube is overset, or cast out by the waves or accident, the Worm leaves it, and becomes in its turn exposed to enemies. To protect itself from these, while a new tube is being secreted, nature has amply furnished the Sao with a series of bristling lances on each side. These arms are of exquisite make, very fine and very sharp; and those of the upper bundle have their points bent and inclined towards those of the lower bundle, which are likewise bent to meet them. Arms like these will inflict wounds on the tiny assailants of the Sao, sufficiently painful to repulse them, and a lethal wound is not necessary."

The Eunicidæ, as a rule, undergo metamorphoses; but a few of them are born in the shape of their parents and in the viviparous manner. The larvæ, in the first instance, are ciliated, and there are one or more special ciliated bands in particular regions of the body, and assisting in locomotion. Some genera have bands at both ends, or at one extremity only. The head of the perfect worm gradually develops, and then the tail out of the larval form, and the ciliated bands are lost. The segments between the head and tail are formed, as it were, by a budding.



THE NERVOUS SYSTEM OF NEREIS (*After Gegenbaur*).

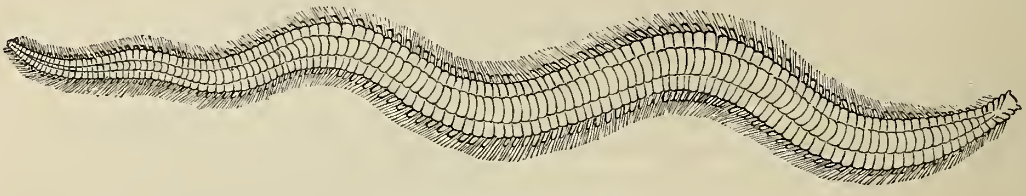
a, upper, *b*, inferior ganglion of pharynx; *c*, ventral trunk; *d*, nerves of mouth, *e*, of antennæ; *f*, eyes placed on superior ganglion of œsophagus.

The family Nereidæ have long slender bodies with two anal cirri, and the head is flat and four-eyed. There are two small middle and two large outer feelers at each side of the mouth. The pharnyx is protrusible, and there are two large horizontally-moving jaws armed with denticles. The parapodia are double, and have sharp spines, but no hair-like bristles. The genus Nereis is very common, and nearly every stone that is turned over near the sea-water edge sets some moving. Gosse describes the Pearly Nereis† a common species, as having a warm brown-coloured upper surface, but the beautiful flashes of iridescent blue that play on it in the changing light, and the exquisite pearly opalescence of the delicate pink beneath, are so conspicuous as to have secured it the title of pearly. The great dorsal vessel is a dark red line along the back. *Nereis pelagica* is another species, which attains six inches in length, and is as thick as a quill. The body

* *Northia tubicola.* † *Nereis margaritacea.*

is brilliant in colour, with flesh and iridescent blue tints. It is a great wanderer, burrowing often in the mud in brackish water marshes and pure sea-water shores. In its larval state, just after the tentacles are developed, it is phosphorescent, and may be seen on the shells of oysters.

The White-rag Worm*, or Lurg, is common on the British shores, and varies from six to ten inches in length, being about three-tenths of an inch wide. It is of a beautiful pearly lustre, and the feet are much developed, and increase gradually in size from the head to about the middle of the body, and then decrease. It lives in the sand, burrowing into it by means of its strong



THE LURG (*Nephthys cæca*).

proboscis, and holding itself fixed by its setigerous feet. When swimming it uses the feet as oars, and moves very quickly through the water. Fresh water soon produces convulsions and death.

A Worm called the Prolific Syllis† belongs to the family Syllidæ. It has the head distinctly seen, and the tentacles are pointed, and the creature has eyes. Dr. Johnston observed that this Syllis is more studious to divide than to unite. When it divides, the posterior half grows a head before it is separated, so that the Worm looks like two individuals joined together, the one holding on to the hinder extremity of the other. Quatrefages has shown that although the two halves are alike when separated, yet they have very different internal structures and gifts. The anterior half continues to eat as before, and conducts itself as an independent creature; but the other individual is devoted to the reproduction of the species, and does not eat. In another allied form, the posterior half becomes self-divided into as many as six parts, each acquiring the cephalic appendages before dividing, and thus the Worm wanders about for a while, with a train of six mothers crammed with ova formed of its own tail. These separate, and die in giving birth to their ova.

The family of Leaf-bearing Worms, the Phyllodocidæ, contains very beautiful Worms, which are easily distinguished from all the other Annelids. They are usually of a linear, elongated figure, and the body is furnished with a series of foliaceous lamellæ on each side, somewhat resembling elytra. They form a border, originating immediately above the insertions of the feet, and are in reality the cirri metamorphosed into leaf-like appendages. These structures are supposed to be useful for respiration; but, in addition to this, they are equally useful as organs of locomotion, for, as they follow the motions of the feet, and are capable of being partially altered from a horizontal to a perpendicular position, "they act as a bank of oars, and must be especially useful when the Worm glides from a solid surface, and finds itself unsupported in the water. Hence the species are quick and lively, and swim with considerable ease." The Phyllodocidæ are provided with a very large proboscis, the under side of which is roughened with rows of fleshy papillæ. The one-branched feet, independent of their leaf-like appendages, are rather small, and the setæ, which spring from them, and of which there is only one brush, are slender and elegant in shape.

PHYLLODOCE KINBERGÜ.

The genus Myxostomum contains little discoid parasites covered with vibratile cilia, and they have four pairs of suckers on the sides of the belly. They have a proboscis and five pairs of

* *Nephthys cæca.* † *Syllis prolifera.*

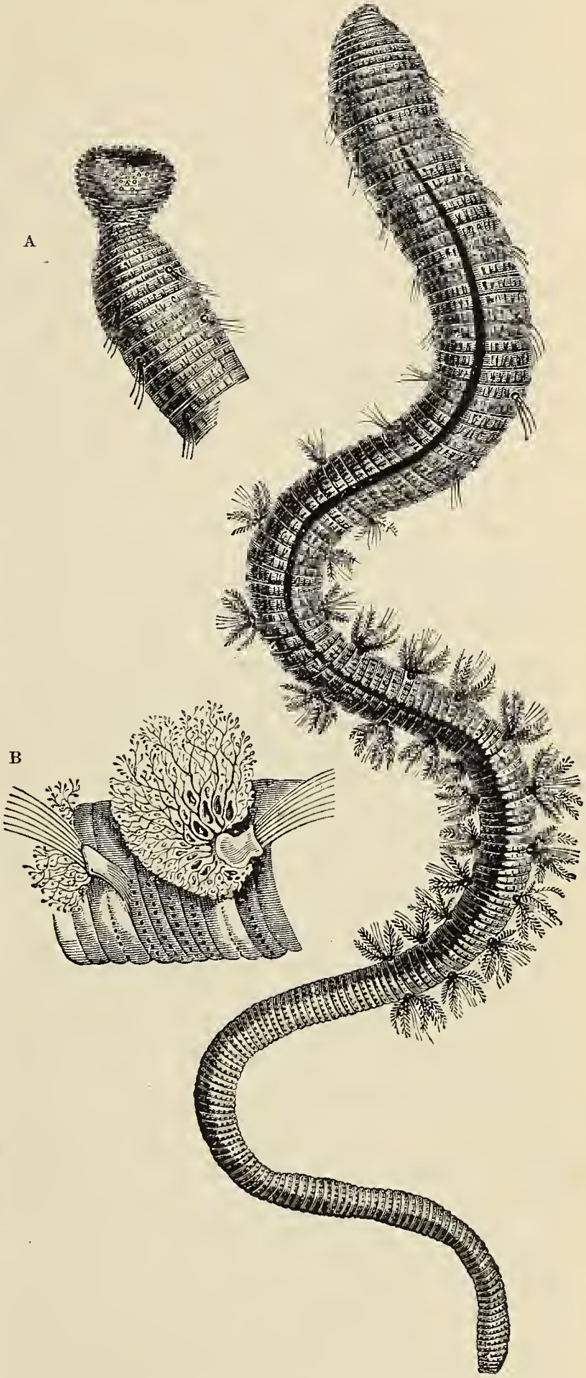
feet, with two hooked setæ and cirri or pimples. There are no blood-vessels. These curious worms live on the surface of Comatulæ, kinds of Echinoderms. Their larvæ are ciliated all over, and the head and feet develop gradually. Probably the position of the worm is amongst the Polychæta.

SUB-ORDER TUBICOLÆ.—THE TUBE-MAKERS.

These worms live in more or less solid tubes, which they construct of different substances such as mud and excreted mucus mixed with calcareous matter, grains of sand and pieces of shells. Some live in mud, or in penetrations in rocks, and others drag their tubes after them. The Tubicolæ have a not very distinct head, a short, often not projectable proboscis, and no jaws. The branchiæ are either deficient, or are limited to two or three segments behind the head. The exception is in the Lob Worm, where they are placed on the back of the median segments. There are numerous filiform tentacles and tentacular cirri on the head, and one or more opercula on it. The feet are short; their accessory structures are small, and are of no use in swimming; but the dorsal lobes of the feet have capillary setæ, and the inferior are projections with hooked setæ or flat hooks. The eyes may or may not be present, and are found in many situations, as are also the branchial tufts, when they are very numerous. The body may be divided into two or three regions, the segments of each differing in their shape and in the kinds of appendages. They are not carnivorous, and are said to feed upon vegetable matter. The long tentacles are of use in building the tubes.

The development of these worms may be in some instances retrogressive; organs degrading and degenerating for want of use. In one group (Spirorbis) the eggs and larvæ are carried about by the mother in a pouch, and when they are able to construct a tube for themselves they escape. The larvæ are mostly free and ciliated, and they gradually lose the cilia, and assume the form of worms, and have feet and tentacles. Some roam about in this state, protected by their membranes, and finally grow eyes and auditory sacs, and begin to reproduce.

The Tubicolæ are divided into numerous families, and a great number of genera. The individuals are excessively numerous, and live at all depths on the sea and ocean-floor. Amongst the most interesting of the families is that* which contains the common Lug or Lob or Fishing Worms.†

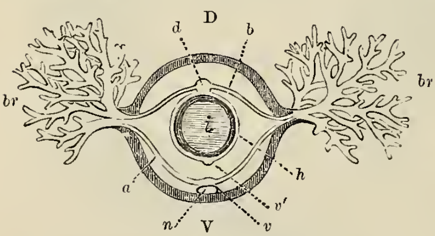


LUG WORM.
A, anterior extremity of body, showing trunk; B, one of the body-rings, showing branchiæ.

* *Telethusidæ.*

† *Arenicola piscatorum.*

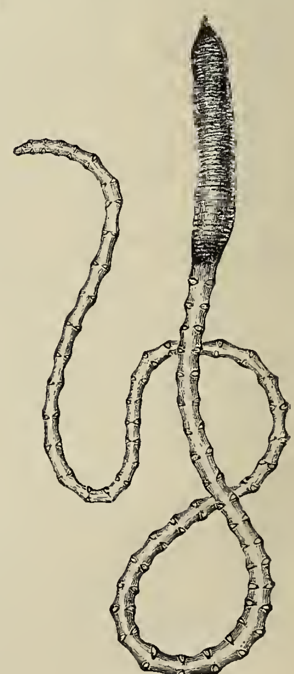
In general form they are long, cylindrical, somewhat inflated anteriorly, and a certain number of the segments are provided with beautiful arbuscular branchiæ. In some of the species these branchiæ are finely tinted, and the worm itself is often of a carmine colour, or of a deeper red, though sometimes it is brownish, and at others of a blackish-green, according, in a great degree, to the nature of the ground in which they are found. The Lug Worm is a common species, and is well known to our fishermen. As Mr. Gosse says, "it is rather an uncouth-looking creature;" and the specimens he found were, in colour, like "what a tailor would call an invisible green." The body is composed of a considerable number of segments, and thirteen of them are furnished with branchial tufts. These branchiæ are arborescent in form, of a red or purple colour, and are said by Gosse, from an examination of the animal in life, to be protrusile, and to consist of a great number of short, incurved filaments, which have the power of independent motion, "moving with a sort of grasping action." The first six segments are provided with setæ only, and have no branchiæ.



TRANSVERSE SECTION OF LUG WORM.
(*After Gegenbaur.*)

D, dorsal side; V, ventral side; *n*, ganglionic chain; *i*, intestinal canal; *br*, branchiæ; *v*, vascular abdominal trunk; *a*, *b*, branchial vessels; *d*, dorsal trunk; *h*, branch surrounding the digestive tube; *v'*, ventral intestinal vessels.

The bristles are described by Gosse as pointing upwards and a little outwards, as very fine, and gradually tapering to a point, where they are clothed with the most delicate barbules. The Lug Worm attains the length sometimes of ten inches, and is found on various parts of our coasts, in rather shallow water, preferring a station near low-water mark, and burrowing there in the sand, or—what perhaps they rather choose—in a somewhat muddy bottom. Their locality is easily detected, from the spiral rolls of sandy excrement, coiled like ropes above the aperture of the burrow, which is about two feet deep. In this hole the worm lives, with its head downwards; and the process by which it excavates this dwelling is very curious and interesting—the worm swallowing the sand as it scoops it out with its anterior portion, and then lining the hole it makes with a glutinous fluid excreted from the skin. In some parts of the English coast the Lug Worm is very much esteemed by fishermen as an excellent bait. Dr. Johnston gives a most graphic description of the scene which occurs, in the neighbourhood of Berwick Bay, on the occasion of a party of "baiters" going to search for these, to them, valuable worms. "Almost at any season," says he, "when the tide has withdrawn itself within the limits of the ocean, the idler who has wandered down to the shore may, perchance, notice a group of men, girls, and boys hieing thither with a glee that he might almost envy. Some carry a small spade, round, and very sharp on the edge, and mounted with a long handle; and others have a little shallow bucket, held by a twisted cord fixed in a hole on each side of the brim. They are a picturesque and happy group. They go direct to a sandy bay, which reaches from the shore to the lowest ebb, and is made a little sinuous by the ledge of rocks on each side that define its limits. Over this bay our group disperse themselves, every one as his experience guides him, to the spot most favoured by the Lug Worm. Here, either directed by some peculiarity in the holes of the surface, or often, as I think, by mere guess, the bait-seeker plunges his spade deep into the sand—not by pressure of the foot as a gardener does, but by the force of the arm only; and then he throws out the sand, whence his attendant boy or girl picks out the writhing worm, and tosses it into his bucket, the bottom of which has been just covered with a little sea-water." The family Clymenidæ inhabit long sandy tubes, and have neither branchiæ nor tentacles, and *Arenia fragilis* may be taken as a type. The Opheliadæ have but few segments, no feelers, no eyes, and one set of branchiæ, limited to the middle of the back, one on every segment. There are stellate microscopic bodies in the perivisceral



ARENIA FRAGILIS.

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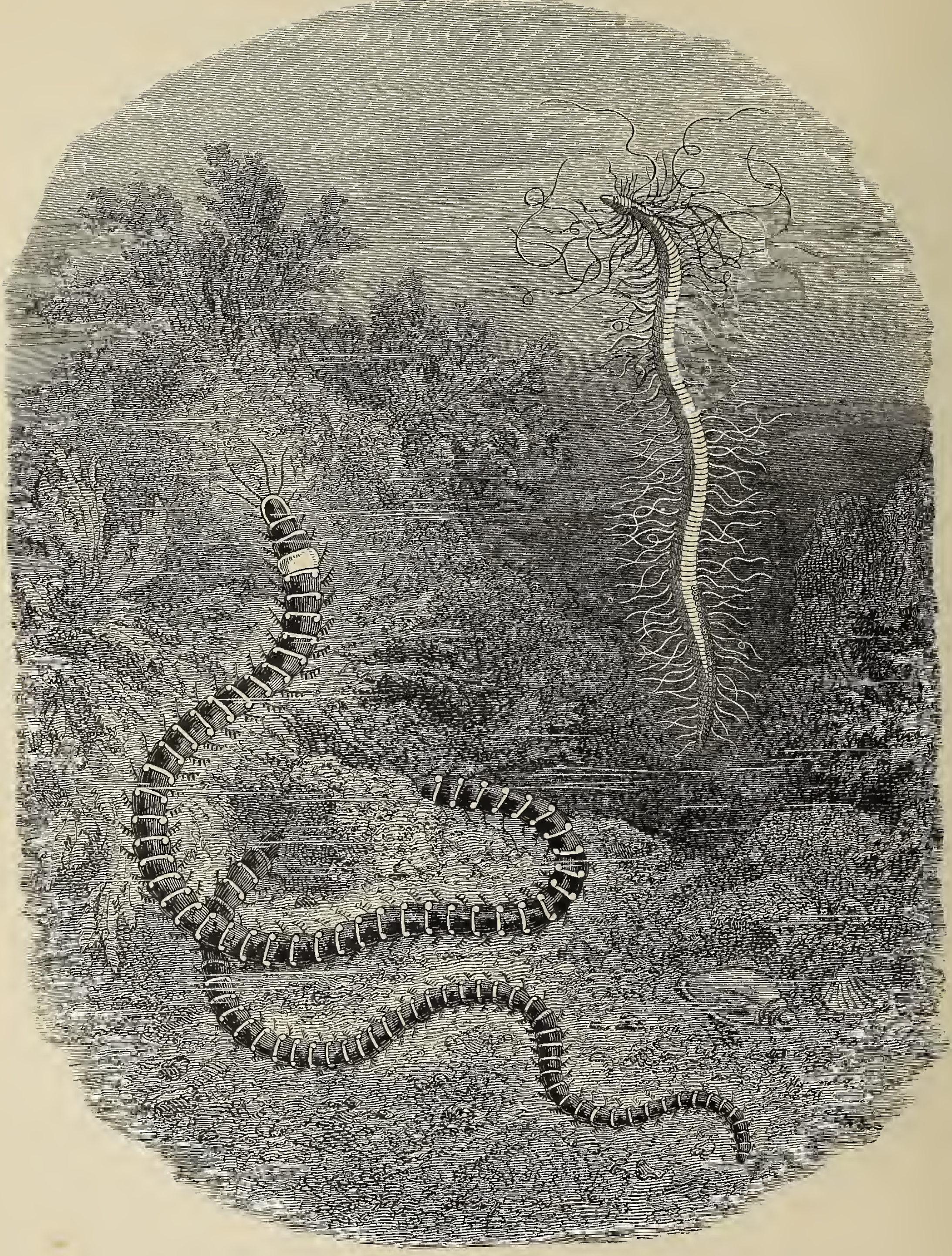


EUNICE AND CIRRATULUS.

fluid. The Ammocharidæ have long segments, with a crown of ramified lobes in front, and their digestive apparatus is within the sanguiniferous system; and the Aricidæ with a slightly depressed round body, made up of numerous short segments, have the head without tentacles and cirri, but the buccal ring carries dentigerous tubercles. They have short lanceolate or filiform branchiæ, and a short, very slightly contractile proboscis.

FAMILY CIRRATULIDÆ.

The genus Cirratulus is characterised by its sub-cylindrical vermiform body being composed of numerous narrow segments, and by its conical head being small, and generally deprived of tentacles. The feet are small, and form a double series along each side. The branchiæ are very peculiar, resemble cirri in their general appearance, and show themselves as long, filiform, tortuous filaments, springing from the back or margins of the segments. The form of the body of these worms is very like that of the Earth Worms (*Lumbrici*), to which they were referred by the earlier writers. One of the most common species of Cirratulus on our shores is the Northern* Cirratule, found on several parts of our southern coasts, such as Devonshire and Cornwall. It varies from three to six inches in length, and individuals even nine inches long are occasionally found. The body is rather less than a goose-quill in calibre, of a brown or yellowish colour. The head is very small, the segments of the body very numerous, and the branchial filaments are found in greater abundance near the head than on the body. It lurks under stones, in a somewhat muddy soil, in which it forms burrows similar to those of the Earth Worm, and into which it retires slowly, when disturbed. The filaments by which it is so remarkably distinguished, and which curl around it like so many parasitical worms, are the branchiæ, or organs through the medium of which the blood is exposed to the influence of the air, and fitted for the purpose of life. So says Dr. Johnston; and in further describing these organs, he tells us that each consists of a large central vessel carrying red blood, surrounded by a white gelatinous transparent membrane, and that they are consequently of a fine red colour. The setæ of the feet are of two kinds. The upper, or superior bundle, is composed of about six—three long and slender, and three shorter, but comparatively stout—and all simple, unjointed, and acute. The inferior bundle has only three in the upper segments, diminishing to one only in the caudal extremity, and all stout and curved, according to Dr. Johnston, like the italic letter *f*. A more beautiful species than the one just mentioned is called the Tentacled Cirratulus, and is possessed of very numerous branchial filaments throughout the length of its body. It is four inches long, rather narrowed in the middle of the body, and consists of nearly 230 segments. The colours of this species are more brilliant than those of *Cirratulus borealis*. Another of the Cirratulidæ† is an inhabitant of the shells of *Cyprina islandica*, one of the hardest and most compact shells of our seas. It lives in a straight or slightly sinuous furrow drilled in the shell. The worm fits the furrow exactly, and when under water it gradually protrudes the tentacles and filaments from the circular aperture. The filaments are laid along the shell, and either kept quiet or in slight movement. It is about an inch long and scarcely a line in diameter, and how it makes the hole and channel in the shell is certainly a great puzzle. It lives on the British coasts.

TROPHONIA PLUMOSA.

The four-horned Spio,‡ with a long slender sixty-jointed tapering body, terminating in two short styles, and with long cirri and two very long tentacles on the head, near four black eyes, is a member of the family Spionidæ. It is pale in colour, and has pink cirri, and makes a very slender tube composed of adventitious matter slightly agglutinated together, and placed usually on Sertularian Zoophytes. Amongst this family are some remarkable forms, which have not only internal ovaries, but also external ones like bunches of grapes in shape (genus Lepidoceras).

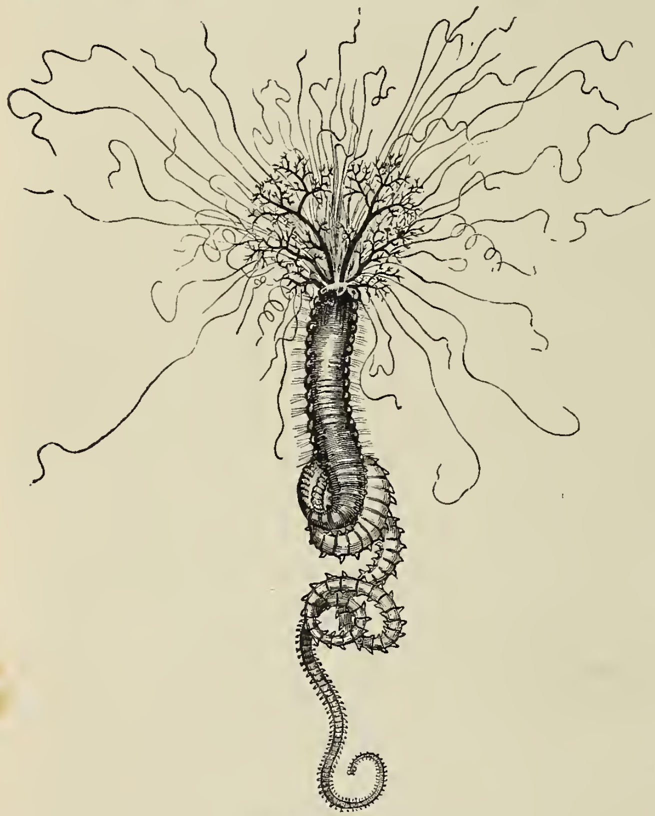
A small worm, from six to eight lines in length, worm-like in shape, with a small head and two

* *Cirratulus borealis.* † *Dodecaceria conchorum.*
‡ *Spio quadricornis.*

great tentacles projecting from it, has on certain segments a branchial cirrus springing from the back, and as long as half the diameter of the body.*

The family Sternaspidæ have very short bodies, the anterior region thick and carrying three rows of setæ, and there is a corneous shield near the end beneath. On the other hand, the Pherusidæ have long cylindrical bodies with two strong forked tentacles on the head, and the buccal papillæ and branchial filaments are retractile. The first or second segments carry very long setæ, and in some the branchial organs are on a peduncle. *Trophonia plumosa* is one of them.

A great host of Tubicolæ live upon most shores, and have their tubes coated with broken shell, gravel, or sand, and membranous within and open at both ends. Some have their tubes visible and always covered with water, and others bury them in sand or mud, raising the orifice a little above the earth. These work between tide marks. Many live in groups, and are said to be gregarious, and their tubes are very fragile, being composed of sand.



TEREBELLA EMMALINA.

All these tube-makers belong to a large family, the Terebellidæ. The animals are worm-shaped, thick in front and narrow behind. The cephalic region is not distinctly separated from the buccal ring, and often has a collar. There are numerous tentacles, filiform in shape, and divided into two groups around the mouth. There is no proboscis, and there are branched or comb-shaped branchiæ on some of the anterior segments. In some genera there is a transverse row of stiff golden bristles on the dorsal margin of the post-occipital segment. The segments are very numerous in some, and the worms attain the length of eight to nine inches, or more. The colouring is very pretty, and the shape of the setæ is lanceolate, hooked, siphon-shaped, and knobbed.

The larvæ of the Terebellidæ are covered with cilia, except at both ends, where several bands of cilia become apparent; they have auditory sacs. This is the case in *Terrebella conchilega*. When growth has proceeded so as to develop feet, the cephalic lobe becomes distinctly visible, and it has two eyes and one tentacle. At first there are only single setæ, but when the Terebella begins to construct its tube, forked setæ and branchiæ appear. Some of the larvæ crawl on the sea floor, and the others swim freely. The full-grown worms have the tubes made up of slimy matter which has entangled pieces of sand and stone; and one forms a case of loose sand large enough to permit it to turn within and to use either end for the projection of its tentacles. A Scottish species covers its body with a web made up of the finest threads, almost invisible from their slenderness and extreme transparence. The web extends far beyond the body, and puts one in mind of that of a Spider. Dalyell states that a specimen nine lines long, had a web covering an area fifteen lines square. The threads are fixed as high as the length of the worm, and below also, and are secured to neighbouring objects. The web serves to support the ova. Moreover, this weaving species constructs a semi-cylindrical shell of sand or mud, but it is not large enough to include the body and head perfectly, so it is abandoned very constantly for a new one.

* *Leucodora ciliata.*

Finally, a common species has its case horizontal and adherent throughout, to its supporting shell or stone. It is generally found on old bivalve shells, is cylindrical, open at both ends, sinuous, and from six to ten inches long, thicker than a quill, and is coated with shell and gravel and pieces of Sertularia.

One of the Tubicolæ, which forms its tube of agglutinated grains of sand, has its home free, conical, and widely open at both ends. The ill-defined head has a row of prominent bristles in two fan-shaped sets above the mouth, which is overhung by a fringe of short channelled tentacles. The branchiæ are in two pairs, on the sides of the third and fourth segments. The thoracic portion of the body is greatly developed, and the segments form setigerous feet on each side, but the tail end is small and indistinctly segmented, and has no feet. *Pectinaria belgica,* which has a straight tube, lives on our sandy shores, within the lowest tide-mark. It varies from two to five inches in length, and stands immersed in the sand perpendicularly , and when active, searches all around the opening with its tentacles for grains of sand, shortening, lengthening, and twisting these organs in a most workmanlike manner, and applying the grains to the top of the rim of the tube. The animal can turn in its tube, which is as thin as paper, for only a single sand grain is placed one over the other, and the whole is lined with a slight silky coating within. It is the type of the family Amphictionidæ, whose genera are world-wide.

The last family to be noticed forms either calcareous or membranous tubes, and contains some of the most beautiful objects of the aquarium. The Serpulidæ have a vermiform body, with short segments usually well divided into two regions, the front, or thorax, and that behind, or the abdomen. The cephalic lobe is continuous with the next ring, which usually has a collar. The mouth is situate between spiral or semicircular branchial fans or laminæ, more or less supported by a dense tissue. There are two or three tentacular cirri. The dorsal lobes of the feet carry fascicles of simple setæ in the front part, and the ventral lobes hooked setæ. In the hinder part, the hooks are on the upper lobes, but they are often absent, and the ordinary setæ also.

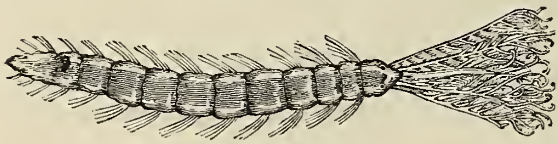
There are two sub-families, the Sabellinæ and the Serpulinæ.

Dr. Baird writes :—"A very handsome species, and one of the most common found on our coasts, is the 'Fan Sabella' (*Sabella penicillus*). The animal is from twelve to fifteen inches in length, and as thick as a common goose-quill. It is of a brownish-orange colour, and composed of numerous segments. There is no proper head, but the anterior extremity is furnished with branchiæ, which form a 'pair of remarkably elegant, large, fan-shaped tufts, of a straw-yellow colour, beautifully spotted and branded with brown, yellow, orange, green, and red, and about two inches in height; each tuft consists, in an ordinary specimen, of more than thirty (sometimes as many as eighty or ninety) filaments, densely fringed, and united together by a common cartilaginous membrane at the base.' The cilia of the fringe are simple, and the uncini, or hooked setæ, are arranged in such a way 'as to resemble the denticles of the tongue of a zoophagous mollusc.' The bristles which their feet bear 'are of a golden yellow, collected into a cylindrical fascicle; and as each bristle is thickened or kneed where the point begins, the apices of the whole are made to converge and form a conical termination.' The tube in which this worm lives is long, flexible, and cylindrical; smooth outside, the mud or fine sand of which it is constructed being cemented by a kind of glutinous secretion. In some of our creeks and tidal rivers these animals abound in immense numbers, and on the coast of Essex they are known to the fishermen by the name of 'Hassocks.' When dredging in the river Roach, I have often come upon banks where they existed in hundreds of thousands, and appear in masses of large extent, growing erect like a standing field of corn."

Sir J. Dalyell gives us a very interesting account of this fine species, under the name of *Amphitrite ventilabrum.* He describes it in great detail, and the formation of its tube is given with graphic accuracy. The little organs which he calls "trowels," and the "scoop," are extremely useful, as the following account clearly shows :—"To catch and collect the muddy material necessary for the work, the branchial fans are spread out into a semicircle, so that when the two are brought into contact a wide funnel is formed. Once in the funnel, the muddy matter is forced down the rachis of the filaments by the play of the ciliary fringes, and brought within reach of the singular organ at the base of the funnel by which the mud is selected and applied, just as a mason would lay lime on with

his scoop, and then mould and smoothen it with his trowel." These organs, described above, receive the pellets of mud which the animal mixes up "with an adhesive secretion, furnished probably by the collar of the cephalic segment, and by the organs just mentioned. It is thus rendered consistent and tenacious, and fit to be employed in raising the edge of the tube. To that position the material is raised by the tongue and trowels, aided by a general elevation of the head; and it is fashioned into shape by the same scoop and trowels, curved over the exterior circumference as far as they can be stretched, and smoothed and polished by their motions, while clasping it with their pressure; and thus the tube is built up." When clear and perfect, says Dalyell, this tube bears the narrowest resemblance to a tube of caoutchouc manufactured by human art.

The branchial plumes are the most striking part of the structure of this worm, and an enumeration of their parts may well strike us with wonder and admiration. "If the plume of an adult," says Sir John Dalyell, "displays eighty branchiæ, with five hundred cilia on each side, here are no less than forty thousand organs endowed with voluntary, distinct, and independent action. So many other parts are alike privileged in their own peculiar motion without the participation of the rest, that it is no exaggeration to affirm that the will of this timid, lowly, defenceless creature is fulfilled through the control of fifty thousand living parts." None of the Annelids, we are told by those who have studied the history of this interesting worm, is more richly endowed with the power of repairing wounds and losses.

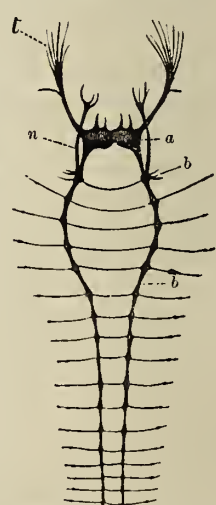


ORTHONIA FABRICI.

One of the Sabellinæ is remarkable for the fewness of its segments—the same number as in caterpillars—and the presence of eye-spots on the front and also on the tail segment. The species *Orthonia fabrici* has a body three or four lines in length, and is vermiform; it has a small fascicle of retractile bristles on each side of the segments, and the branchial tentacles are one-third of the length of the body, are straw-coloured, and rise from three stalks forming two dense tufts. The tube is cylindrical, and about twice the length of the body, and it is placed erect, on the roots of small seaweeds (*fuci*). It is made of fine mud, cemented by a glutinous secretion, and lined within by a skin. If the worm be removed and placed in clean water, it soon forms a new tube-skin; and when the worm has its tube formed, it is very lively, expanding its dense branchiæ in a wide circle.

The larvæ of this family have one zone of cilia, and have two eye-spots and two ciliated auricular appendages on the back, in front of the zone. Segments are proceeded by setæ in the relative position, and the auricular appendages divide and form the four principal branchial rays, and their number augments by budding. Finally, the segments and setæ become developed.

The sub-family Serpulinæ have a ciliated thoracic membrane, and the ventral and dorsal surfaces partly covered with cilia, and usually there is an operculum at the extremity of a tentacle. They make a calcareous tube. In the genus Serpula, the operculum which closes the tube-end is horny and rarely calcareous.



NERVOUS SYSTEM OF SERPULA CONTORTUPLICATA.
(*After Gegenbaur.*)
a, upper, *b*, lower ganglia of pharynx, *b'*, ventral trunk; *n*, nerves of mouth; and *t*, of antennæ.

Serpula vermicularis, or *contortuplicata*, inhabits a round shelly tube, tapered regularly backwards, and marked on its dorsal surface with a more or less distinct keel. It is about three inches long, and its aperture is circular, with an even or somewhat everted rim. Many tubes are usually found growing together, adhering to some old shell, a bit of broken pottery, or a stone, all much intertwined, and mutually adherent. The worm itself is only about an inch in length, and there is a well-marked difference between the thorax and abdominal portion. The former carries on each side prominent tubercles in place of feet, which are vigorously protrusile, and within which bundles of strong bristles are thrust to and fro. On the upper part, extending half across the back, is a row of microscopic hooks, wielded by long, thread-like tendons, which are fixed on mechanical

principles to the attached end of each hook. By the aid of these, the Serpulæ very cleverly withdraw themselves with lightning-like rapidity on alarm. "These organs are formed on the model of a hedger's bill-hook, only that the edge is cut into long teeth. Carefully counting them, I have found that each Serpula carries about 1,900 such hooks on its corselet, and that each of these being cut into seven teeth, there are between 13,000 and 14,000 teeth employed in catching the lining membrane of the tube, and in drawing the animal back." The branchiæ consist of most elegant comb-like filaments, richly coloured, arranged in two rows around the front extremity, one row on each side of the mouth. They are graduated in length, and are so affixed that, where the rows meet behind, they can be thrown in, so that a vertical view of the circular coronet shows a great sinus in it. These brilliant gill-tufts form the most attractive feature in these elegant worms, and are individually most exquisite examples of mechanical contrivance. Examined under a low microscopic power, they present a most charming spectacle. Each filament consists of a pellucid, cartilaginous stem, from one side of which springs a double series of secondary filaments, like the teeth of a comb. Within both stems and filaments the red blood may be seen with beautiful distinctness, driven along the artery and back by the veins (which are placed close side by side), in ceaseless course, contributing a very striking spectacle. The exterior of these organs is set with strong cilia, so arranged that the water-current is vigorously driven upwards along one side of the filament, and downwards along the other." This current brings the food destined for the nutrition of the animal into the funnel formed by the branchiæ, at the bottom of which is the mouth, along with a quantity of water, which, again, is expelled by means of a ciliated lining of the hinder parts in a strong current impinging against the closed end of the tube, and which carries with it all extraneous or fæcal matters. (Gosse).

SERPULA VERMICULARIS.

Protula Dysteri is a many-segmented form, and its delicate tube is white, calcareous, more or less wavy, and attached to a solid body by one end. Rising from a fixed base, these worms unite together side by side in irregular bundles, which leave spaces here and there between the tubes like a solid network. Each tube has a circular section, is thickened at intervals, and obscurely annulated. When active, the Protulæ issue from the tubes, and each spreads out its eight branchial filaments and displays its red cephalic end. Another species, with the tube about five or six inches long and about the thickness of a goose-quill, is very cautious, and will remain in its tube for hours without projecting its branchial tufts; but when they are slowly put forth, and then expanded, their beauty is extreme. On the slightest vibration of the water the worm retreats. This worm has no operculum, and the genus has a vast range, being found in the Mediterranean, the Atlantic, and West Indies. Huxley has shown that when the Protula attains a certain length, all the segments behind the sixteenth become separated as a new zooid, by the conversion of the seventeenth segment into a head and fore part, as in *Syllis prolifera.*

The dredgings in the North Atlantic yielded many small tubular shells, slightly curved and open at both ends. One end is wider than the other, and the whole may be from one to two inches in

length. They were the tubes of *Ditrupa subulata*, one of the Serpulines. This animal has two sets of branchiæ, rolled up spirally, and there are six fascicles of bristles on the body. The operculum is concentrically striated. These worms live at considerable depths, and the coral *Caryophyllia borealis* grows upon them. More Serpuline-looking, but very slender thread-like shining tubes in masses, are often found below low spring-tide mark in Devonshire, and they belong to the genus Filograna.

The genus Spirorbis is very familiar to everybody who picks up the long seaweed on our coasts. On it there are small flat, spiral, or twisted shells, with at least three turns. It is a tube formed of carbonate of lime, and is attached by one surface entirely. When living, this tube contains a little worm which projects its filamentary branchiæ at one end, and which has one or two trap-doors or opercula. The young undergo a kind of incubation within the tube, in a process or pouch, within the body of the parent.

THE SUB-CLASS HIRUDINEA.—THE LEECHES OR SUCTORIAL ANNELIDA.

Formerly, nearly everybody was familiar with the appearance of a Leech, for one or more were frequently ordered to be applied to tender and inflamed parts of the body by medical men. But now that blood-letting is not required to be done so frequently, the Leech is really very rarely seen. Some persons who sell Leeches keep them in darkness, and crowd a multitude together; but more reasonable people keep a few in a fresh-water aquarium with a secure top. There the Leeches may be seen, occasionally swimming with an undulatory up-and-down movement, and they then look flat, long, and rather pointed at both ends. When they come to rest at the bottom or fix on to the sides of the glass, their shape alters, and they become shorter, thicker, and more cylindrical, retaining, however, some flatness at the under part, and a narrowing fore and aft. But it will soon be observed that there is a flat disc on each narrow end, or head and tail, and that it can be applied to the substance on which the Leech is moving or resting, so as to fix the body as if it were a sucker. There are neither legs nor feelers, and the outside of the body is covered with rings, one behind the other, and from 95 to 100 in number. The colour of the Medicinal Leech is greenish-olive or very dark green, with six yellow-reddish or yellow bands along the back, and the belly is yellowish-green with black spots.

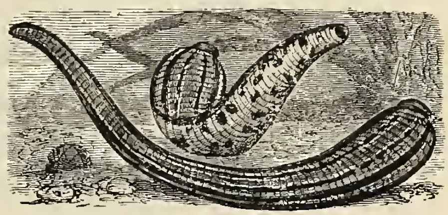
On taking one out of the water, it will diminish much in size, and will contract, become much harder, and swollen in the middle, and on permitting it to rest on the hand it will after a while begin to fix the front sucker to the skin, and then a sharpish prick or series of pricks is felt, and the Leech begins to elongate and to move its body in a slightly undulatory manner. After some minutes the body begins to swell, and the front sucker is well fixed, and the part immediately behind it is narrowed, the rest of the body being plump. After a time the Leech becomes many times its usual thickness, and it suddenly lets go its hold, falls off, and some blood comes from the spot on which the sucker had fixed, as well as from the mouth of the Leech, which is then seen to be at the bottom of the sucker. It has removed a certain quantity of blood from the hand, and the wound has been made by three jaws disposed in a triangle, and having their fine, curved edges toothed. The suckers act by their muscular fibres clasping the surface and expelling the air or water, and this brings the jaws in contact with the surface, and each is moved backwards and forwards, the teeth being downwards and the fixed point upwards. The result is three wounds, each radiating from a common point.

In their early life the Leeches fix on to the larvæ of insects in the water and suck them, and after more growth, fishes and frogs are attacked and have their blood sucked. The Leeches then frequently leave the water and wander in damp places, and if they have the opportunity, they creep on to the skin of warm-blooded animals and gorge themselves. Their sucking is followed by a prolonged fast, and indeed it is very wonderful how long some Leeches will live without food. Possibly from six months to two years are occupied in the process of digestion. Leeches grow very slowly, and some years elapse before they arrive at maturity, and they are not fit for medicinal purposes before the age of a year or eighteen months. There are, according to Cobbold, three species of leeches used in medicine, the Grey*, Green†, or Dragon‡ Leech. When it was the fashion to use Leeches in the olden time, the medical man himself had the compliment of being called a "Leech"—a term appropriate enough so far as healing is concerned, but singularly inappropriate in all other respects,

* *Hirudo medicinalis.* † *Hirudo officinalis.* ‡ *Hirudo interrupta.*

for no profession is so self-denying or so generous as the medical. The employment of Leeches is diminishing year by year, and now they are hardly ever used in England. In Paris, between the years 1825 and 1830, three millions of Leeches were used, and it was calculated that thirty millions were employed in France and England every year. All the ponds and marshes where Leeches were bred, or were found in a state of nature, were nearly exhausted. Now the rate of mortality is less, and Leeches seek other prey.

The Leeches have ocelli in the form of black specks; they vary in number according to the genus, and are placed in pairs. There may be from one to five pairs, and they are very sensitive, and are disposed on the anterior part of the front sucker. The Leeches appear to dislike certain scents and greasy substances, and their skin is exceedingly sensitive to pungent substances, such as salt. Moreover, from their behaviour in rising and sinking in clean water at certain times, they would appear to feel alterations in barometric pressure.



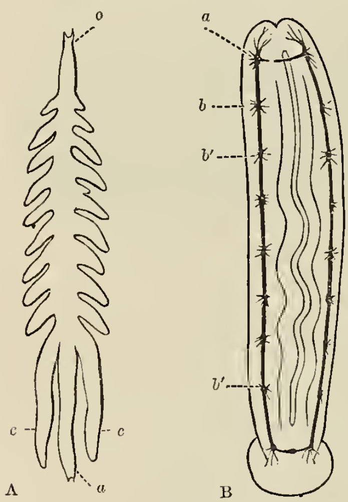
THE MEDICINAL LEECH.

With regard to their bodies, the numerous rings do not correspond to as many segments, there being from three to five to each somite or segment. The skin is smooth and rarely tuberculated, and it has two kinds of unicellular glands. One set secretes mucus generally, or only at the mouth or sucker, and the other produces a chitinous material which forms cocoons, in which the eggs are included. Three layers of muscular fibres exist—the circular, the radiating, and the longitudinal. The nervous system consists of a ventral cord, divided into ganglia at regular intervals, and there are twenty-three in the common Leech, and the anterior and posterior ganglia are the largest, and seven are fused in front, into one mass. Above the pharynx the branches of the front ventral ganglion unite to form a ring and an upper lobate pharyngeal ganglion. A single nerve lies beneath the intestine, and it has ganglion cells; and many nerve-twigs terminate in the centres of little depressions covered by clear cells—the cup-like organs which are situated on the head and hinder, but not hindmost rings of the skin. The mouth is in or below the anterior sucker in the sub-class as a whole, it leads to a muscular pharynx, and some genera have a protusible proboscis which has retractor muscles, but no teeth. The jaws are made up of calcified chitine. There are salivary glands in the gullet, and the œsophagus leads to a long stomach, which has nine side-pouches or cæca. These cæca open into the stomach, and vary in number with the genera; usually they are simple, but in Clepsine they are branched. The pylorus has a circular contracting muscle, and the short intestine passes backwards between the two hindmost cæca, and the anus is dorsal above the hinder sucker. The circulatory system contains a red fluid with colourless corpuscles, and it flows in a small body easily between the organs and the skin, which resembles a series of sinuses or narrow ways. These may form two lateral pulsating vessels. In the Leech this "pseudo-hæmal" system consists of a median dorsal vessel, a median ventral cavity, in which the ganglionic nerve-cord lies, and two longitudinal trunks which anastomose with one another, and give off a network of vessels to the muscular layers. The respiration is effected by the skin, and in the genera Branchelion and Ozobranchus there are some processes of the skin at the margin of the body, which may have to do with respiration. The excretory organs, are tubes with glandular walls symmetrically arranged along the ventral aspect; they are either closed internally or open within, by a ciliated funnel-shaped orifice, while the outer opening may be on a small wart or tubercle on the side of the body. These are called segmental organs.

One great Leech belonging to the genus Macrobdella from Valdivia is an internal parasite, and measures two feet five inches in length. In a genus which frequents shell-fish—for many species live in the sea—the skin is ciliated. In another there are tubercles, and one genus has bristles. All the Leeches lay eggs, and they may be deposited singly or in numbers, and in this case they may be covered with a viscous web or with a spongy envelope called the cocoon, as already mentioned. When the young are hatched, they keep within the cocoon, and in from twenty-one to thirty days burst forth, and either keep close to their envelope or their mother, for a short time afterwards. They do not undergo metamorphosis, and whilst in some the sexes are separate, they are united as a rule.

Malacobdella grossa, belonging to the family Malacobdellidæ, is found between the mantle and the branchiæ of the Mollusc *Cyprina islandica.* It is nearly two inches long, and is flat, soft, ringless, and of an uniform flesh colour. The Histriobdellidæ have the posterior part of the body split, as it were, and the head has tentacle-like processes. There are two horny jaws in the pharynx, and the intestine is simple. *Histriobdella homari* lives upon the eggs of the Lobster, and it looks like the larva of a dipterous insect. The next family, the Acanthobdellidæ, have a flat fusiform body, pointed in front and armed on either side by well-hooked setæ. There is a posterior sucker, at the bottom of which is the anus.

The Branchiobdellidæ have the body almost cylindrical in shape when it is stretched out, and the segments are unequal. There are no eyes, and there are two flattened jaws, one over the other. There is a sucker at the posterior end. The species live on the gills of Crabs and under the tail and at the base of the antennæ of the Lobster.



A, INTESTINAL TUBE OF SANGUISUGA. B, NERVOUS SYSTEM OF MALACOBDELLA GROSSA. (*After Gegenbaur.*)

A. *o*, pharynx; *c*, posterior pair of intestinal cæca; *a*, anus. B. *a*, pharyngeal ganglion; *b*, first ganglion of the lateral nervous trunk, equivalent to the sub-œsophageal ganglion of other worms; *b′*, the succeeding ganglia.

Some Leeches, which have a more or less protrusible proboscis, are termed the Rhynchobdellidæ, and they are divided into the Ichthyobdellidæ and the Clepsinidæ. The first group are the Fish Leeches, and the mouth is at the bottom of the anterior sucker. There are four eyes. Some species of Piscicola live on fresh-water fishes, others on marine fishes. The genus Branchelion has foliated-looking lateral appendages, and lives on the Electric Ray and on the Sole. In the Clepsinidæ, which are short, flat, gradually enlarged in front with three rings to each segment, and with an oval sucker slightly distinct from the rest of the body, there are from one to four pairs of eyes. The lower part of the body forms a kind of pouch for the eggs, the embryos of which escape and hang on to the mother. The proboscis is cylindrical, and the body is so transparent that the viscera can readily be seen; moreover, these Leeches move in a geometric manner by their suckers, or can contract their body into a ball shape like a Wood Louse. They carry the young attached to the belly for a considerable time after birth. *Clepsine bioculata* lives in places with but little water, lurking under stones and beneath the bark of decaying trees, and it feeds on the vegetable matter surrounding it, as well as on fish. Some were fed by Sir J. G. Dalyell on a vermilion-coloured larva of a dipterous fly. "When the prey was introduced to vessels containing the Leeches, they raised themselves on the sucker as if surveying around; then some one, bolder than the rest, advanced, and endeavoured to affix itself to the victim, which, being effected, the position was pertinaciously maintained in spite of its writhings and struggles."

The Skate-sucker* belongs to the genus Pontobdella, which has a leathery knobbed skin, and is about four inches long. It has no jaws, but it sticks fast and sucks out the juices of the fish in a most cruel and pertinacious manner. Its eggs are contained in capsules, and there is one young one to each capsule, which is attached to some substance or other in the sea. *Piscicola geometra*, the Great-tailed Leech, is found on perch and carp and fresh-water fishes, and it has large suckers, in comparison with its size. The genus Hæmentaria is used medicinally in Brazil; it has a two-lobed sucker.

The genus Hirudo, comprising the true Leeches, belongs to the sixth family, and its description has been given already. Associated with it in the same family are several genera, of which the following are remarkable. The term Horse Leech is used rather widely, and two genera have species so named.

Hæmopsis sanguisuga is called Horse Leech by the French, and it lives in lakes and ponds, being four inches long and half an inch broad. The long body widens backwards, and the large mouth has a protruding upper part. It has ten eyes, and is green and black on the back and yellowish-green on

* *Pontobdella muricata.*

the belly. The teeth are not well developed. It appears to be terrestrial in its habits sometimes. They are common in Egypt, and the soldiers of Napoleon suffered much from them in his campaign. They also attacked the horses and cattle. These must not be taken for true Leeches, some species of which, especially in the tropics and even to the north, lead a life amongst damp vegetation, and attack Europeans with great ardour. Such are the Leeches of the Himalayas, Ceylon, the Philippines, &c.

Another so-called Horse Leech belongs to the genus Aulostomum, but it does not appear to suck blood or to worry horses.

The glutton Aulostome, writes Dalyell, "is an active, bold, and clever animal, frequently crawling out of the water, and apparently always ready to quit the vessel. None of the tribe surpasses it in voracity. Few animal substances are rejected. All kinds of fish, dead or alive, seem acceptable. Penetrating the cavity of the larger fresh-water shells, this Horse Leech takes up a permanent dwelling there, until emptying them of their contents, should it be able." The same author notices that these Leeches are cannibals, and that they will swallow even dead Leeches of different kinds. It feeds on Earth Worms, Grubs, and Snails. It has a long intestine with only two cæca. The genus Bdella has an oval sucker and four pairs of eyes, and is African, and the species of Nephelis have thin bodies and no jaws. One of these is the Eight-eyed Leech of our ponds and lakes, and is a very active animal. It moves with an undulating movement, does not quit the water, and often fixes itself by the terminal sucker, and waves the body to and fro. They are carnivorous, and yet do not prey like the carnivorous Leech. They attack almost every small animal that comes in their way, and swallow it, more or less whole, by placing the sucker over it and then dilating their gullet. Small Mollusca, Earth Worms, Planariæ, and even their fellows, are readily devoured. They are small, being from one and a half to two inches long and two or three lines broad. They are usually brown in colour, and may be speckled with yellow dots. They deposit their eggs in capsules, each of which contains from six to twenty ova, embedded in a gelatinous mass.

CHAPTER II.

THE GEPHYREA, THE WHEEL ANIMALCULES, THE ROUND AND THREAD WORMS, THE FLAT WORMS.

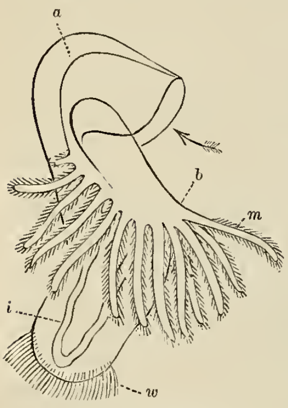
GEPHYREA—Bolster-shaped Worms—Characters—ROTIFERA, THE WHEEL ANIMALCULES—Structure—Classification—The Philodinidæ—The Brachionidæ—Other Families—THE NEMATHELMINTHA, ROUND AND THREAD WORMS—Characters—The Thorn-headed Worm—THE THREAD WORMS—The Genus Trichina—The *Trichina spiralis*—Description—Reproduction—Their Effects—The Whip Worm—The Genus Filaria—The Guinea Worm—The Ascaris—The Lung Worm—The Genus Mermis—THE FLAT WORMS—The Tape Worms—Characters—Reproduction—The Beef Worm—THE TREMATODA—THE TURBELLARIA—Classification of *Vermes.*

CLASS GEPHYREA.

THERE are many kinds of Marine Worms which resemble at first sight the Holothuria, or Sea Cucumbers, belonging to the Echinodermata (see Fig. 17, p. 272). Their bodies are usually long, cylindrical, without "feet," and there is no distinct separation into segments. A little trouble distinguishes the group, for the Gephyrea have neither calcareous bodies in their skin nor ambulacral regions on the body. These bolster-shaped Marine Worms live at great depths, with their bodies in the sand or mud or under stones. Some exist in the shells of Mollusca, and others in the interstices between corals. Footless, without a series of lateral bristles and suckers, these worms have their locomotion singularly defective; but a great many species have a proboscis, which is more or less retractile, and which is terminated by the mouth, and it may be used as an organ of prehension, and, to a certain extent, of locomotion. It is said that some species * perforate limestone; others certainly penetrate soft clays,† and one group, which has a crown of tentacles formed by numerous branchial filaments, resides in tubes.‡ The species of Bonellia lead a more or less wandering life. When one of these Gephyrea is placed in water, after a while it elongates and appears to be soft, and the trunk or proboscis is put forth,

* Genus *Thalassema*. † Genus *Phoronis*. ‡ Species of *Sipunculus*.

but on touching the animal it contracts immediately, becomes narrow, cylindrical, sharper at both ends, and hard. Both in the uncontracted and contracted condition, the body is swollen out here and there for a time and then contracted again. The Gephyrea have the sexes separate, and the young undergo metamorphoses. Most of them have a superior cerebral ganglion or a double one, an œsophageal nerve-collar, and a ventral ganglionic cord. This cord differs from that of the class Annelida, for although it gives off nerves from its sides there are no separate ganglia at regular distances; but it is covered with a layer of cells which environ a canal, and it is placed within a blood-vessel. There are eye-spots directly over the brain ganglia, in some genera, and the proboscis is a tactile organ. The skin is analogous to that of the worms generally, but the transverse furrows do not amount to segmentation; numerous glandular follicles supplied by nerves are on the skin, and open out by pores in the epidermis. Bristles are rare, and there is chlorophyll in the skin of Bonellia. The muscular coats beneath are stout, and the outer is circular and the inner longitudinal, and the proboscis is retracted by bands of muscles from the body-wall. The proboscis is ciliated and also covered with bristles. In some the pharynx is armed with teeth, and there are salivary cæca opening into it. The intestinal canal is small in calibre, is within the perivisceral cavity, is long, and usually coiled. It is, as is the body cavity also, ciliated within. The vent may be dorsal, posterior, or even at the junction of the proboscis and body. When the vascular system exists, it consists of two long vessels, one along the median ventral line and the other dorsal, running along the intestine. In the genus Sipunculus these vessels are joined by one around the front of the body, within, and vessels are given off from it to the tentacles. The blood may be colourless, red, blue, or violet, and there may be a similar fluid in the perivisceral cavity containing amœboid and flagellate corpuscules.



LARVA OF GEPHYREA.
(*After Gegenbaur.*)

a, cephalic lobe, upper lip; *b*, lower lip; *w*, vibratile crown; *i*, intestinal canal; *m*, muscular fibres.

The genus Priapulus has a branchial tuft at its hinder end, and Echirurus has branched structures, receiving vessels from the ventral vascular trunk opening into the intestines. The tentacles of some act as respiratory organs. Finally, there are traces of excretory or segmental organs, in the form of four ciliated pouches on the lower part of the body, and they vary in number and use, being sometimes in relation to the process of reproduction. The males are not so numerous as the females, and differ in shape. In one genus (Bonellia) the male is like a Planarian in shape, and lives in the female. The eggs hatch and the embryos are free-swimming and unlike the parent. Their mouth is in the front part, and is overlapped behind by a double-lobed upper lip, which is round and ciliated, and on the ventral side there is a small ciliated lower lip or several ciliated processes. These become tentacles in some genera. Behind these lobes and mouth there is a curvelet of cilia, and then follows a long bag-like body with an intestine and anus. All this embryo or larva is not changed into the adult, but only a part grows into the mature form. Many of the larvæ resemble the Rotifera in their circles of cilia, which surround the mouth, anus, and body.

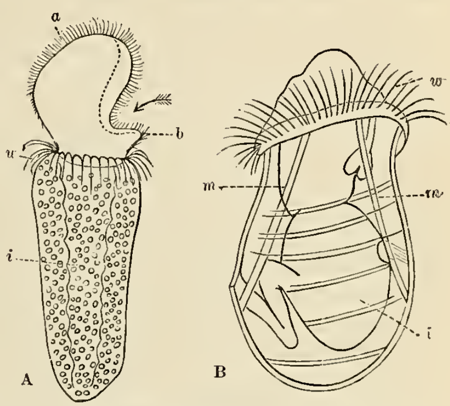
SIPUNCULUS BERNHARDUS.

The Gephyrea are divided into three orders. The Gephyrea inermia have no bristles, and the mouth is at the extremity of a more or less retractile proboscis. Priapulus is the typical genus of the first family of this order. They are not uncommon in the Northern seas. The genus Sipunculus is the most important genus of its family, the Sipunculidæ, which have a retractile proboscis, tentacular arms, and a twisted intestine. Phascolosoma is another genus.

The second order is that of the Gephyrea armata, which have bristles on the anterior part of the body, and posteriorly also. The genus Bonellia, already slightly noticed, belongs to it, and also the genus Echirurus, which has an undivided proboscis.

One genus (Phoronis) forms the third order of the Gephyrea tubicola. *Phoronis hippocrepia*

lives in a tube, and has a crown of tentacles on the dorsal surface, the mouth being in the midst of them, and the anus opening far in front on the dorsal aspect. The embryo has a two-ciliated body, and that behind the mouth is produced into several lobes, and fringes the free edge of a broad fold of the back, which arches over the mouth. This young form has been called Actinotrocha. As it grows, a part of the skin of the lower part grows inwards, like a pouch, and becomes connected with the middle of the intestine of the embryo. Then it grows out again and covers the intestine in the form of a loop with it, as a projection. This forms the foundation of the adult form, and the tentacles of the embryo or larvæ grow into those of the adult. It is like the larva of an Echinoderm.



LARVA OF PHASCOLOSOMA (A) AND OF SIPUNCULUS (B). (*After Gegenbaur.*)

a, cephalic lobe, upper lip; *b*, under lip; *i*, intestinal canal; *w*, vibratile crown; *m*, muscular fibres.

CLASS ROTIFERA.—THE WHEEL ANIMALCULES.

Leeuwenhoek found in the rain water of a leaden gutter animals which were considered animalcules, about the size of a small grain of sand, and which produced currents in the water by means of slender organs or limbs. These they protruded at pleasure. They had bodies of the shape of a pear, with a short stalk, divided into two tails for fixing them on to objects. The microscope gradually increasing in its powers, observers were able to distinguish vibratile cilia upon a protruded disc-like structure, capping as it were the minute animal, and the optical illusion of a rotatory wheel of hairs produced by the uninterrupted succession of the strokes given by the cilia of the disc, has caused these beautiful and nearly transparent creatures to be called Wheel Animalcules, or Rotifera. The general surface of the body of the Rotifer is not ciliated throughout, and is made up of a layer of clear transparent chitinous tissue, which even becomes shell-like in some, and is ornamented. It is quite evident, under the microscope, that the body has cross markings and constrictions behind, amounting to imperfect segmentation. In front, or nearer the part out of which pass the discs with cilia—the trochal discs—the constriction is not usually seen, but transverse markings are often visible, so that the whole may be indefinitely marked with six segments. This outside coating may have spines or rigid bristles or hairs on it, and when there is a shell or carapace, this is secreted by the skin or by a special organ. The Rotifera have a digestive apparatus, and the mouth is a funnel-shaped cavity situated in the middle or on one side of the trochal disc; its walls are ciliated, and at the bottom of it is a muscular pharynx, or mastax provided with a peculiar armature or moving jaws. There are four pieces in the mastax, two side ones, the smaller, and two central, forming the incus. Muscles are attached to the movable mallei, and work them forwards and backwards, so that their ragged free ends work the food on the incus. A short œsophagus, also ciliated, leads to a digestive cavity lined with cells and dilated in front, giving off a large cæcum on either side. Behind, the digestive cavity narrows, becomes intestinal, and may open externally by a passage or vent. In some Rotifers the digestive cavity has no second opening, and is a sac without an intestine, and in the males of some forms there is no digestive track whatever, a solid cord of tissue existing there. The position of the mouth, close to the trochal disc, enables the cilia of this interesting structure to provide it with food by their lashing and current making. The cilia of the digestive tract assist, and the morsel is crushed and smashed up, before entering the stomach, by the mastax.

ROTIFER VULGARIS.

A spacious cavity exists between the digestive organs and the inside of the skin and sides of the body of the Rotifer, and this is of course a perivisceral cavity. The outer opening or vent (cloaca) of the intestinal canal has a large thin-walled vesicle opening into it, which contracts and dilates regularly. This contractile vesicle has two delicate water-vessels, like narrow convoluted tubes which pass forwards giving off branches, and finally form a maze of tubes in the trochal disc. The branches are open at their ends, and as they are outside the digestive organs and inside the walls of the body

they must bring water from without into the perivisceral cavity, and in the main trunks cilia are seen moving with a flickering motion.

A large single nervous ganglion is placed on one side of the body near the trochal disc, and one or more eye-spots are placed upon it. Some Rotifers have a little sac filled with calcareous matter close to the ganglion, and it is probably a rudimentary organ of hearing. Moreover, a spur-like forceps armed with setæ is often found projecting near the ganglion, and it may be a nervous organ. The sexes are separate, and the ovarium and testis are simple glands which open into the cloaca already mentioned. The eggs are laid and left, or in some they are attached to and carried about by the female. In some Rotifera the eggs are of two kinds, and are termed summer and winter eggs, the last being enclosed in a shell.

In the sides of the body, beneath the skin and surrounding the perivisceral cavity, are muscular fibres in bands; some pass longitudinally and others encircle the body, many being of striped fibre. The jointed tail end is very telescopic in its movements in some Rotifera, and the terminating pincers hold on to objects by their muscles. But in some Rotifera the later stage of life is not passed as a freely-moving creature. Some form tubes to live in, and then their body ends in an adhesive disc. However, the young of these, especially of the genus Lacinularia, enjoy a free-swimming life, and have a circle of cilia around the large or mouth end of the body, and another circle around the tail end. This immature Rotifer is analogous to the larvæ of some of the worms already noticed, and as the adults have perivisceral cavities, a pharyngeal armature and water systems, and are more or less segmented, the necessity of classifying the Rotifera with the Vermes is evident. The trochal disc can be retracted and everted in some Rotifers, and as soon as it is well out the cilia begin to move, lashing forcibly in one direction, and producing by their general action whirlpools and currents in the water. They have to do with the providing of food, with removing impure and giving pure water to the water system, and also largely with locomotion, for when the foot is loosened, off starts the Rotifer, head first, and it guides itself here and there with the hinder part of its body. The trochal disc varies greatly in its construction, and forms a means of classification. Its margin may be continuous or divided, there may be lobes to it resembling more than one disc, and it may be provided with long tentacular processes. Finally, it may be used as a creeping organ, the Rotifer moving with its head and tail, over substances, like a Leech.

The Rotifera are found very universally in fresh, salt, and pure water, in pools, ponds, streams, and gutters. They even manage to exist in moist earth, and some make homes of the open cells of mosses and algæ; some are parasitic within other animals. They are tenacious of life, and will revive on the application of moisture after they have dried up to a certain extent, but perfect desiccation is fatal. Their shape differs considerably in the different genera into which the class may be divided; some are sac-shaped, others are vermiform; one group lead a social life, being attached by their long tail ends to the number of forty or more. A fusiform shape is common, or that of an elongated cone. The manner in which the trochal disc is retracted within the body and again put forth is as remarkable as the similar process seen in some of the fixed Rotifers, whose delicate crown of long tentacles is unfolded and protruded with great grace and perfectness. The activity of these interesting microscopic animals is great under the stimulation of the sun and pure water containing minute animalculæ and vegetable organisms. They move and feed freely under such circumstances, directing themselves here and there, choosing the best spots for feeding, and fix themselves so as to work their disc cilia to advantage, or unfixing their forked tail, they move off by the same agency.

The classification of the Rotifera is not in a satisfactory state, and whilst Ehrenberg arranged them according to the peculiarities of their trochal discs, Dujardin classified them by their methods of locomotion. There are some very curious forms which have not all the characters of the Rotifera, and yet which have so many that they are allied to them, and this increases the difficulty. Thus in the parasitic genus Albertia, which lives in the intestines of Slugs and Earth Worms, and is $\frac{1}{80}$th to $\frac{1}{47}$th of an inch long, the body is cylindrical, vermiform, rounded in front, with an oblique orifice, around which there is a ciliated lip. There is a short conical tail, and the mastax is rudimentary, there being only one or two forceps-shaped pieces which seize the food.

A Rotifer of the genus Lindia* also has a vermiform body, rounded in front; but it has no

* *Lindia torulosa.*

rotary organ, cilia, or eye, and it has a tail-like foot with two conical and short segments at the end. The mastax differs from that of the ordinary kinds, and is very complicated. The animal is about $\frac{1}{57}$th of an inch in length. Another and smaller species (*Taphrocampa annulosa*) has a fusiform annulose body with a forked tail, and there is no rotary organ. Moreover, the genus Balatro, which lives upon the surface of Oligochete Worms, has neither rotary organs nor eyes, and the tail is bilobed. Several genera, such as Chætonotus, Ichthydium, and Dasydites, have no mastax nor eyes, nor trochal discs; but the body is furnished with bristle-like hairs, downy hairs, and cilia on the ventral surface; usually there are two tail-like processes. They are minute, and are from $\frac{1}{200}$th to $\frac{1}{700}$th of an inch in length, and would appear not to be Infusoria, but really Rotifera, allying the class to the Turbellarian Worms.

MONOLABIS GRACILIS.

The first family of the Rotifera is that of the Philodinidæ, and they are free-swimming forms, which can also creep like Leeches, the ends of the body being alternately fixed and loosened. They have two wheel-like rotary organs, and the body is somewhat spindle-shaped, and very contractile, so that it can be formed into a globose shape, and the powers of extension are considerable. The tail end or foot is jointed like the slides of a telescope. The genus Rotifer belongs to this family, and the common Wheel Animalcule is *Rotifer vulgaris*. It has a white fusiform body $\frac{1}{24}$th to $\frac{1}{48}$th of an inch long, gradually narrowed to the foot which has two horn-like toes. The anterior part of the body has a proboscis ciliated at the end, and the two eyes are placed there. The wheels are two in number, are round, and placed at the sides of the front part of the body.

Rotifer citrinus has a yellow body, and *Rotifer tardus* has the body deeply constricted into segments.

The genus Philodina has the two eyes on the region below the extreme end, and in general appearance the species greatly resemble Rotifer. Some are rose red in colour, and the ova when deposited are red. The ova are deposited in little heaps, and the parent remains in their neighbourhood, and even looks after the young.

A common species* has two frontal red eyes, and at the tail end there are two horny processes and three terminal points or toes. They are large, being from $\frac{1}{18}$th to $\frac{1}{36}$th of an inch long, and are common. In the genus Monolabis there are no horn-like processes.

BRACHIONUS AMPHICEROS.

The other Philodinidæ have no eyes, and in the genus Callidina the horn-like processes on the foot are present, there being six, and there is a proboscis. This proboscis, like that of most other Rotifers, appears to be an entry and exit for water, and it certainly is used in locomotion. One of the genus is parasitic on Crustacea, such as Gammarus and Asellus. One of the Rotifers found in Egypt has neither eyes, nor proboscis, nor horn-like processes on the foot, and the rotary organs are placed at the ends of processes on the front of the body. Another Egyptian form (*Typhlina viridis*) is simpler than the last mentioned, and has no processes for its rotary discs. Probably both of these Rotifers are young Philodinæ.

The second family, the Brachionidæ, have a broad body more or less enclosed in a shell, or lorica. The foot is composed of short segments, and the rotary organ may be double or of three median and two lateral parts, these last only being rotary organs, the cilia of the others remaining extended without motion during the action of the other.

The lorica, or shell, is thick in this family, so much so as to prevent the internal organs being readily seen. The genus Brachionus has an eye on the neck, and the foot is forked. The mastax is very visible, and the crushing pieces are terminated by finger-looking ends made up of the same kind of hard skin or chitine that forms the lorica, which has projections on it fore and aft on either side.

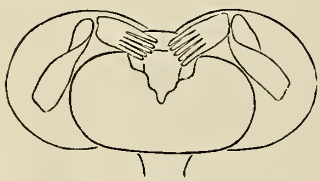
The species are numerous, and the individuals also, and they are about $\frac{1}{50}$th to $\frac{1}{70}$th of an inch in length. One of the genera of the family differs from the last in having no forked foot, and the lorica is striated or has facets on it. Some of these Anuræa, however, have plain shells, but in most there are fixed or movable spines on its edges. Some of the family have two eyes, and one

* *Actinurus neptunius.*

genus (Pompholyx) thus gifted has no foot, whilst the genus Pterodina has a disc on its foot, and is a very globose-looking form, and it carries its eggs for a time.

In the last genus to be noticed of this family (Noteus) there are no eyes, and the foot is forked, and the body has spines in front and behind, being usually large, or from $\frac{1}{10}$th to $\frac{1}{70}$th of an inch.

Amongst the Rotifera, with the trochal discs or rotary organs divided, are some in which the division is greater than in the two families just noticed. In the family Hydatina and that of Euchlanidotæ the wheels are many parted, and the first have no lorica, whilst in the latter the shell is very well developed, and has curious appendages, such as setæ in the genera Euchlanis and Stephanops, hooks in Colurus, horns in Salpinus. There are spears or respiratory tubes in Euchlanis, and a helmet in Stephanops. In the genus Monostyla the foot is a sharp style, and in Mastigocerca the foot is as long as the body, or $\frac{1}{72}$th of an inch, and the lorica is prismatic. The genus Squamella has four eyes. The species of this genus carry their eggs attached to the outside of the body.



JAWS OF BRACHIONUS BREVISSIMUS.
(*After Ehrenberg.*)

In many of the family the muscular fibres by which the shape of the body is changed are very visible. The nutritive organs are very obvious, and the intestine is simple and conical, with or without the part which represents a stomach. The water system, with its tremulous flapping of minute cilia within the tubes, is visible, and in most the nervous system is to be seen. There are no crushers or mastax in the genus Enteroplea; it has no eyes, and it is thus a very simple Rotifer, and segmentation in any degree barely exists, the small foot being forked. In Hydatina, another genus, there are no eyes, two jaws, and they are divided to show numerous teeth. *Hydatina senta* was the Rotifer which Ehrenberg especially studied, and it is common and very transparent. Its species are not very small, or $\frac{1}{200}$th of an inch long.

Of the family Hydatinea, in which there is not an investing lorica, and the rotary organ is multiple, there are no less than eighteen genera, and they are characterised by the absence or number of eyes, the position of these organs, the nature of the foot and appendages to the body. There are several distinct rows or circles of cilia, which are distinctly separated from each other, forming the multiple wheel or rotary organs. Except in the genus Polyarthra, which has no foot, all the other genera have a long pincer-like process resembling a tail, and this genus is characterised by a single eye on the neck, and by the presence of six cirri or fin-like processes on each side of the body.

POLYARTHRA PLATYPTER

The species of the genus Notommata are sometimes parasitic, and undergo some degradation of form, and *Notommata tardigrada* has the rotary organ greatly diminished. Two species live within the beautiful microscopic alga, called *Volvox globator*, and another in the vesicles of a Vaucheria. The well-formed species have a single eye and a forked tail.

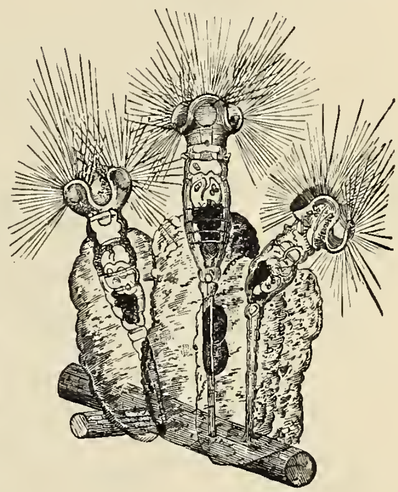
Notommata longiseta has two setæ in the position of the tail, and several times longer than the body.

The Triarthræ have two eyes, and *Triarthra longiseta* has a tail, or foot, three times as long as the body, and very long cirri also. It moves in a jerking manner, and is $\frac{1}{200}$th of an inch in length. It carries its ova attached to its sides, and may exist in such multitudes as to colour the water a milky white. Gosse has described *Asplanchna Brightwelli* and *A. priodonta*. The females have jaws with a single tooth and a single eye-spot, and they are without feet and the end of the intestine. The males have neither jaws, pharnyx, nor stomach.

The family Flosculariдæ contains some very beautiful forms of Rotifers, but they are very aberrant from the group as a whole. The body is elongate, and the tail or foot is long, more or less imperfectly segmented and fixed. They are for the most part protected by a tube made up of a gelatinous excretion of the body, and extraneous substances or pellets of their excrement. The rotary organ is much modified, and is partly incased in some and is lobed in others, whilst in

many it consists of a host of delicate filaments placed on a disc, which has, however, a circle of cilia on its under edge; or some fine tentacles may arise in a ring and be ciliated. Under all these conditions the cilia and appendages can be withdrawn into the body by the longitudinal muscular fibres, and also gradually everted. Moreover, the animal itself withdraws down its tube if disturbed, and comes forth again to a certain extent. There is usually, but not invariably, a stomach and mastax, and in nearly all there are eyes. In one set of genera the rotary organ is flexuous and extended, and has only one deep cut in it; and in the genus Megalotrocha the alimentary canal is singularly developed, and there are two eyes. In another group the rotary organ is entire, the genus Ptygura being the type.

The genus Floscularia has the lobes of the rotary disc three to six in number, has a tentacle-like proboscis at the side, and the cilia on the rotary organ are of two kinds, some very long and excessively slender and comparatively motionless, and others very small and not readily seen at the base of the long ones on the inner side of the lobes. The number of lobes varies, and five or six are commonest; they are thickened at the free margin. All the species make tubes of a delicate gelatinous secretion, and live on the surface of the leaves and twigs of water-plants. *Melicerta ringens* is a beautiful species of its genus, and is frequently found on water-plants, especially on *Potamogoton crispus*. The rotary organs are four-lobed, and the bodies are each in a tubular cavity.



FLOSCULARIA TRIFOLIUM.

The young are very interesting on account of their having a circular pre-oral disc, and two eye-spots, besides a second circle of cilia behind the mouth. Their shape, and this distribution of rings of cilia, cause them to resemble the larvæ of Annelida, and ally the class Rotifera very definitely with the Vermes. The genus Lacinularia has a bilobed rotary organ deeply incised ventrally, and there is a double crown of cilia. The individuals of a well-known species (*Lacinularia socialis*) unite, and remain fixed in the midst of a gelatinous environment.

Limnias ceratophylli, a form resembling the last somewhat, has only two lobes to its rotary organ, but its shell gets dark with age, from its collecting foreign bodies on it. It is a very typical form.

The genus Stephanoceros has five tentacles, instead of lobes of the rotary organ, and they are ciliated. It uses them to clasp its prey, and the body is attached by the base to a transparent carapace. The length of *Stephanoceros Eichhornii* is $\frac{1}{36}$th of an inch.

The genus Œcistes probably comes into this family, and one species which has been studied by Mr. Hudson makes pellets of its fæces, and piles them up gradually as a wall to its gelatinous tube.

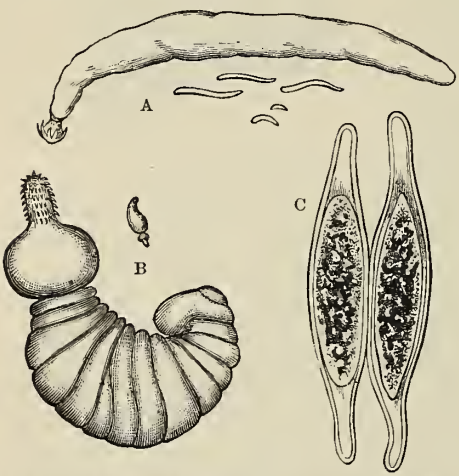
In considering the classificatory position of the Rotifera, the segmented condition of the body, the presence of a water system and perivisceral cavity must be remembered. The nature of the mastax and the rudimentary organs of special sense, the method of locomotion of some, and the tube-making of others should not be forgotten. And when these very characteristic peculiarities of the Vermes are considered, with the fact of the resemblance of some immature free-swimming Rotifers to the ciliated larvæ of some Vermes, the propriety of placing the class in that great group must be admitted. The Rotifera are not Infusoria, for their ova undergo a development not noticed in that group. Some minute worm-like animals, with a rounded head and ten or eleven segments, the last of which is forked, which belong to the genus Echinoderes (*Dujardin*), seem to link some of the Rotifera to the lower Crustacea. They are marine, have no limbs, but the body segments have paired setæ, and the head has recurved hooks. The nervous system is a single ganglion, and has eye-spots on it. Moreover, a Rotifer of the genus Pedalion (*Hudson*) has jointed setose appendages.

CLASS NEMATHELMINTHA.—THE ROUND AND THREAD WORMS.

A host of worms, mostly parasitic within man and the lower animals, and a few leading a free life, belong to this class. All have cylindrical unjointed bodies, which are, however, marked with rings,

or they are filiform, and narrowed at each end, and furnished with papillæ, or stylets, on the anterior extremity. The sexes are separate. The class is divided into two orders, the Acanthocephala and the Nematoidea, and in both there are no rudimentary organs of locomotion, such as false feet, and it is only in rare instances that setæ capable of moving are found. Usually the skin is thick and the muscular system within it is highly developed, so that these worms wriggle, twist, and move in a serpentine manner with great vivacity and persistence. Within the muscular layer is the visceral cavity which contains the blood and the digestive and reproductive organs. There are no special organs of circulation and respiration, but there is a nervous system, and there is a tactile power in the front of the body, especially when there are papillæ developed there. Simple eye-spots and eyes have only been noticed in the non-parasitic kinds. Great diversity exists in the shape of the digestive organs, and in one order they are absolutely deficient. The excretory organs exist, and are various in their shape and distribution. In almost every instance the sexes are in different individuals, and the egg may produce a worm like the parent, or a form which has to undergo metamorphosis of very strange kinds, one part of the transformation taking place inside one animal, and the other in a second and different kind of unwilling animal host. The parasitism of most is constant, but in some a host is frequented at one time only, of the life of the parasite. The parasitism is of a nature deserving the name, and the worms live in their unwilling host, and exist by absorbing its juices.

The Acanthocephala, or Thorn-headed Worms, have a genus whose name is explanatory of the principal peculiarity of the order.* They have a projecting trunk or proboscis which is armed with hooks; the body is ovoid and oblong or cylindrical, and has neither mouth nor digestive organs. The trunk is used to fix the worm, or to enable it to penetrate the coats of the intestine of its host. The nervous system is composed of a ganglion with large cells, which give forth a nerve to the proboscis and another to the body; but there are no sense nerves. The species of Echinorhynchus are frequently parasitic within Invertebrata in their first stage of metamorphosis, and within Vertebrata in their second, and become perfect there. Thus eggs containing embryos are excluded, and these escape in the form of little elongate bodies armed in front with temporary hooks. They live in the water free, and are swallowed by, or penetrate from without, through the tissues into the digestive organs of small Amphipod Crustacea. After a while they cling to the tissues of the stomach and intestine of the Crustacea, and penetrate them, getting into the cavity beyond. There they loose their hooks and undergo a metamorphosis, becoming round or elongate things which might be called nymphs. If the Crustacean should happen to be swallowed by a bird or fish, the Echinorhynchus is not killed, but it escapes from the prey and fixes on to the mucous membrane of the digestive organs of the swallower, and then attains its perfect form, living by taking in, through its skin, the nourishing juices of the food of its host. This process of development may be considered one of alternation of generation. Examples are very common. Thus one kind of Echinorhynchus gets into the Water Flea (*Gammarus pulex*), and this is swallowed by the fresh-water fish, and another kind gets into the food of water-fowl, and becomes parasitic within it.



A, ECHINORHYNCHUS ANGUSTA (*nat. size and enlarged*); B, ECHINORHYNCHUS NODULATA (*nat. size and enlarged*); C, EGGS OF DO. (*enlarged*). [*After Busk.*]

ORDER NEMATOIDEA.†

The Thread Worm group are round worms, with a long, fusiform, or filiform body. They are mostly parasitic, and usually have a mouth, a swollen gullet, and a straight digestive canal. The cylindrical body, generally very long for the width, has papillæ on the front of the body around the mouth, and sometimes sharp pricks and hooks, or a style in the interior of the buccal cavity. There is often a very muscular, dilated pharynx, and there may be a granular substance in the spaces left

Echinorhynchus.

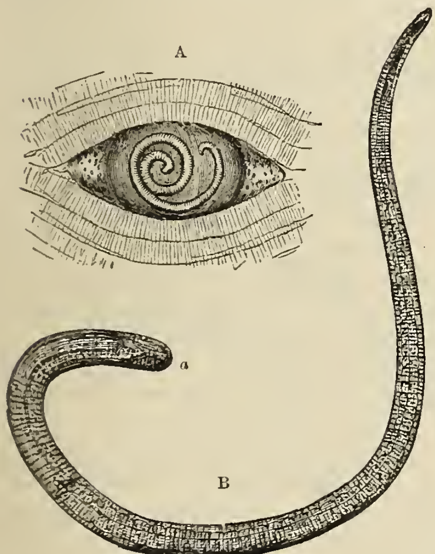
† Greek, *nema*, a thread.

by the muscular fibres or glands. The chitinous tube of the pharynx may have longitudinal projections called teeth, but the office of the gullet is that of a sucker or tube. In some Nematoidea the intestinal canal, in part or wholly, undergoes retrogressive development during the parasitism. The skin, more or less tough, and often striated across, is formed of several layers partly composed of fibres, and rests on a soft, finely granular tissue with nuclei. Beneath this is a musculo-cutaneous envelope with flat and fusiform muscular fibres. The surface of the skin may be covered with ridges, tubercles, spines, or hair, and moulting takes place in the young. Some Nematoidea have eye-spots, at the end of the body, with or without refracting bodies in them. Most have the sexes separate, and usually the males are smaller than the females.

INTESTINAL CANAL OF A NEMATOID. (*After Gegenbaur.*)

Of late years much attention has been paid to a very remarkable Nematoid parasite which has been called *Trichina spiralis* by Owen. Gritty particles were found in human muscles, by the late Mr. Hilton, F.R.S., of Guy's Hospital, who recognised them as the results of parasites. Sir James Paget, when a student, first determined the existence of the minute worms which produce the gritty parts; and Robert Brown, the botanist, assisted, by lending his microscope to the now distinguished surgeon. In the year following, Professor Owen described the worm scientifically, from specimens sent him by Mr. Wormald, Paget's colleague. Leuckart discovered the history of the parasite, tracing it to its source and method of propagation; and Zenker explained the symptoms of infected men, and detected the young in the act of migration.

The worm was named from its very commonly being seen in a capsule, rolled up in a spiral shape. When mature and able to reproduce its kind, and therefore fully developed, *Trichina spiralis* is minute, and the male is about $\frac{1}{18}$th, and the female $\frac{1}{8}$th of an inch in length. The body is rounded and filiform, usually slightly bent upon itself, and is rather thicker behind than in front. The head is narrow, finely pointed, unarmed, and has a simple central, minute, oral opening. The tail of the male has a bilobed end surrounding the vent. The female is stouter than the male, bluntly rounded posteriorly, and the reproductive outlet is placed far forwards. The eggs measure $\frac{1}{1270}$th of an inch from end to end. As observed in the muscles of the human body, the Trichinæ are young, not mature, and are spirally coiled worms in the interior of small oval cysts, which are scarcely visible to the naked eye. They measure $\frac{1}{75}$th of an inch in length, and $\frac{1}{136}$th of an inch in breadth, and often are gritty from the presence of salts of lime. Sometimes they are not thus encysted, and they measure $\frac{1}{25}$th of an inch in length, and $\frac{1}{390}$th of an inch in breadth. The history of the life cycle of the worm is as follows:—



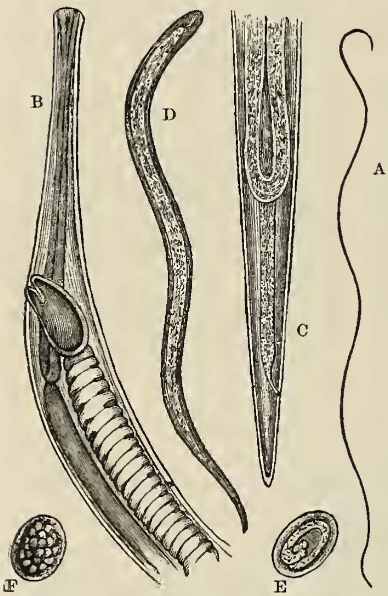
TRICHINA SPIRALIS.

B, worm a, head A, worm coiled up in capsule or cyst in muscle.

The mature and reproductive Trichina inhabits the intestinal canal of Mammalia, including man, and its life lasts from four to five weeks, and they attain their full development and ability to reproduce on the second day of their introduction to their locality. The eggs of the female are hatched, as it were, within her uterus, and produce minute hair-shaped embryos there, and there may be from ten to fifteen thousand of them. The embryos are expelled from the body of the mother whilst in the intestines of the victims, and they soon drill their way through the mucous and muscular tissues of the parts, and then, traversing even serous membranes, get into the muscles. There they assume the form known as *Trichina spiralis*. The importance of the discovery of this series of changes is great, for it is clear that if the Trichinæ can be kept out of the digestive organs of an

animal, it cannot suffer from the painful and dangerous disease which is set up by the young worms, as they grow to a certain life-stage, in the muscles. And, moreover, the only manner in which the Trichinæ can get into the digestive system is by their being swallowed alive, with pieces of improperly cooked muscle in which they are encysted. Men are infected by eating badly-cooked pork, the pig happening to suffer from the presence of the worm in its muscles. Leuckart stated that, as a rule, "swine obtain their Trichinæ from rats, to which latter we also, as natural bearers, have to convey them." Cobbold has shown the stupendous number of Trichinæ an animal may have within its muscles at one time, and he proved that 80,000 were in an ounce of pig's flesh belonging to an animal part of which had been unfortunately eaten, and had produced an epidemic.

The "Whip Worm"* has a long filiform neck two-thirds of the length of the whole body, and the surface of the skin has, on one side, a longitudinal band of minute wart-like papillæ. The Whip Worms infest the cæcum and the upper part of the great intestine or colon, and many thousands have been found in the human subject.



FILARIA BANCROFTII. (*After Cobbold.*)

A, female (*nat. size*); B, head and neck; C, tail; D, free embryo; E, egg with embryo; F, egg with mulberry cleavage of yolk.

Cobbold describes the wonderful story of the life of one of the species † of the genus Filaria, and notices that the body of it is like a hair, uniform in thickness, and that the head has a simple circular mouth without papillæ. The neck is narrow and about one-third of the width of the body, and the tail of the female is single, bluntly pointed. They are three inches and a half long and $\frac{1}{90}$th of an inch broad. The eggs are about $\frac{1}{1000}$th of an inch in length, and the embryos derived from them are $\frac{1}{200}$th to $\frac{1}{225}$th of an inch in length.

The embryos were first discovered in human urine, and Cobbold got eggs and embryos from a man from Natal whilst searching for the parasite called Bilhariza. In 1872 Dr. Lewis found these microscopic worms in the human blood, described them, and gave the species the name of *Filaria sanguinis homini*. In 1876 Dr. Bancroft found the eggs in the blood, and discovered, subsequently, the mature form already noticed, and observed that immense numbers of minute living ones are passed from its body.

Dr. Manson, in 1878, found the immature or embryonic Filaria in the stomach of Mosquitoes which had sucked the blood of man, and probably also that of birds. The female Mosquitoes, after gorging themselves with blood, repair to stagnant water to deposit their eggs, and during the four or five days thus occupied the Filariæ within undergo remarkable changes. Subsequently they become more fully developed, and escape from the Mosquitoes into the water, and may be drunk by man.

The largest known Nematoid Worm is called *Eustrongylus gigas*, the male measuring a foot and the female more than three feet in length. The breadth of this huge worm is half an inch at the thickest part. This worm is known to occur in a great variety of animals.

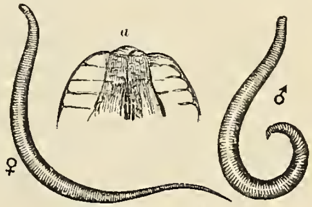
The Guinea Worm‡ is a Nematoid measuring from one to six feet in length, and having the thickness of one-tenth of an inch. The body is cylindrical, and has a pointed tail and a convex head, with a central mouth surrounded with papillæ. The body of the female encloses a prodigious number of hatched embryos when she is mature, and they may have the opportunity of escaping from their human host from the sores produced by the adult. The embryos escape into water and become parasitic in the small crustacea of the genus Cyclops, and undergo a change of skin and subsequent growth. This condition of larval development lasts about five weeks, and when the larvæ become perfect they may be accidentally drunk with the Cyclops by men and animals.

The Thread Worm,§ which is so frequently a parasite of children, also affects old people. The male worm, according to Cobbold, measures one-sixth of an inch, and the female from one-third to one-

* *Trichocephalus dispar.* † *Filaria Bancroftii.*
‡ *Dracunculus medinensis.* (Cobbold.) § *Oxyuris vermicularis.*

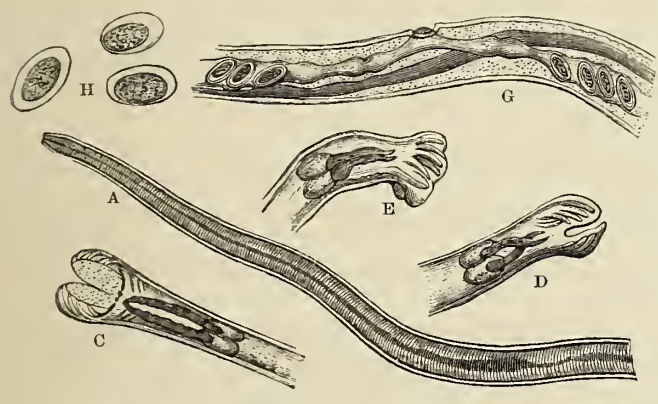
half of an inch in length, and the latter has a long hair-like tail with a three-pointed end, the tail of the male being blunt. The body is fusiform, and the front end is narrowed at the truncated head, which is sometimes rendered very conspicuous by a bulging of the transparent membrane which surrounds the mouth. This has three papillæ around it, and leads to a triangular œsophagus. There is no doubt that the worm is introduced in the form of an egg. The worms live in the cæcum, which is their proper position. They stray to the lower bowel and produce irritation there.

Several species of Ascaris are parasitic within children and adults, and affect monkeys, horses, dogs, pigs, bears, oxen, mice, birds, and marsupials. The species infecting man and the pig are sometimes identical, and this is the case in the example which must be taken as the type. The large round worm, which measures from four to six inches in length in the male, and from ten to fourteen in the female, is at first sight not unlike a pale Earth Worm. They are narrowed at each end, and the body is elastic and marked by numerous fine cross striations. This *Ascaris lumbricoides* is usually found solitary or in small numbers in the upper and middle part of the small intestine; from 100 to a 1,000 have been found. They wander into the stomach and are cast forth, or they may get up into the nostrils and escape. They may make their way through the coils of the intestine into the cavity of the body, producing inflammation and abscess.



THE THREAD WORM.
a, mouth.

The Lung Worm* is often fatal to calves, and a closely allied species attacks lambs. The eggs and embryos of the Lung Worm are found within the common Earth Worm, which swallows them mechanically, with its food of soil. Cobbold placed some of these embryos, or larvæ, as he calls them, which he got from an Earth Worm, on to the fronds of watered ferns, and he noticed them increase in size and organisation. Doubtless the parasites escape in due time from worms, and are devoured by their next hosts with their vegetable food. They do not go into the stomach, but pass into the bronchial tubes and set up much and often fatal irritation. A Strongyle† affects the stomach, however, and they are found in the fourth stomach and duodenum of Australian sheep especially. The Palisade Worm of the horse is a Strongyle,‡ and is remarkable for the severe injuries it does its host in its passage through the tissues. According to Leuckart, they pass into the body of an intermediate bearer before entering the stomach of the horse. From the alimentary canal they pass through the tissues and enter the blood-vessels, causing aneurism, and thence they seek to regain the intestinal canal, where they arrive at sexual maturity. It is during their migratory efforts that they give rise to dangerous symptoms, not unfrequently causing the death of yearling foals.



STRONGYLUS PERGRACILIS. (*After Cobbold.*)
A, head and neck; B, C, D, E, tail of male; F, tail of female; G, section to show termination of oviducts; H, eggs.

One of the Nematoids allied to the Strongyles§ has the male with a tail, surrounded by a ring or crown of fine, lancet-shaped flaps connected together by a delicate web. Probably these worms have something to do with hog cholera, a disease of the pork-producing districts of the United States. The gapes of fowls and other birds are produced by worms in the trachea or main air tube|| and the disease may be cured by careful operations.

The so-called grouse disease depends on more than one worm parasite, one of which is a Strongyle.¶

* *Strongylus micrurus.* † *Strongylus contortus.* ‡ *Strongylus armatus.*
§ *Stephanurus dentatus.* || *Sclerostoma syngamus.* ¶ *Strongylus pergracilis.*

The genus Mermis has species which are parasitic within Insecta, and at a certain time they make their way out, by perforating their hosts, and hide themselves in the soil. They there reproduce, and the embryos are born viviparously and pass some time in the ground. They wander in search of an insect host, the caterpillar of a Tinea, or Moth, for instance, which they penetrate by means of a sharp stylet, that is hidden within the head when not used. *Mermis nigrescens* emigrates *en masse* out of insects, during hot weather, and being found on the ground in great numbers, gives rise to the popular belief that "it rains worms." After this emigration, the embryos live in the pharynx of a Planaria. The Humble Bee (*Bombus terrestris*), and others of the genus, are the unwilling hosts of a curious worm, one-fifteenth of an inch thick and an inch long, white in colour, blunt at either extremity, and covered with knobs, about 800 in number. This worm is the female of a species of Sphærularia, and the male is 28,000 times smaller than the female, and is permanently attached to her. Another family of these Nematoidea contains the genus Gordius, the embryos of which have a mouth, and are found within the bodies of carnivorous water insects. They penetrate outwards and get into the water and become sexually mature. The embryos coming from their eggs penetrate the larvæ of water insects, such as those of Tipulidæ and Ephemeridæ, where they become encysted. Then the carnivorous water larvæ and beetles swallow the others, and of course take in the parasites which rupture their cysts and live free in the visceral cavities of their bearers.

The Anguillulidæ are mostly non-parasitic Nematoid Worms, and some of them are known as paste and vinegar eels. Others live in the mucous secretions of animals, and some are dwellers in mushrooms. One gives rise to a diseased condition of the wheat ear. The young are hatched from eggs laid by the parent in the ear, and they become encysted. When the wheat dies down, the larvæ are set free and wander on the moist earth until they meet with some young wheat plants, up which they creep and lodge themselves in the developing ears. Here they become sexually mature, and nourish themselves at the expense of the inflorescence.

ORDER CHÆTOGNATHA.

Allied to the last-mentioned family of the Nematoidea are the species of the genus Sagitta, which are associated in this order. They are long transparent worms with a special mouth armature and pectinate fin-like feet, placed horizontally at the sides of the body, and their rays united by a web. The head is distinct, and has two sets of hooks which simulate jaws on each side of the mouth. They swim freely in the sea, and live on small Crustacea.

CLASS PLATHELMINTHA.—THE FLAT WORMS.

These are the most lowly organised Vermes. Many are parasitic within animals, and some live in mud or in water, hiding under stones.

They are divided into three orders, of which the first is that of the CESTOIDEA,* or Tape or Ribbon Worms.

The Tape Worms, which are parasitic within many vertebrate animals, including man, live in the intestinal canals of their hosts, and are readily recognised by their long, flat, many-jointed bodies, narrow and small heads usually armed with hooks and suckers suited for clinging on, and gradually narrowing tail end. Some genera have species of enormous length, which consist of hundreds of joints or metameres behind the head, and others have the head and a hinder part not jointed and of no great length. None have any digestive organs, the nutritious juices of the host passing into the worms through their delicate integuments; and no special organs of sense exist. In the Tape Worms, both long and short, the head or scolex divides during growth behind more or less into a joint or metamere, which is called a proglottis, and in this last the reproductive organs are developed, there being none in the head itself. As growth proceeds, the successive joints are given off from the back part of the head, so that a long chain of them is produced, the oldest metamere being that at the tip of the tail. All these metameres can produce ova. After a while, the time depending upon the maturity of the egg-producing apparatus, some of the metameres break off and are set free from the rest of the worm, which still grows on as before. The growth of the metameres from the back part of the head is thus a kind of budding, and as each metamere, when detached from the

* Greek, *kestos, a girdle.*

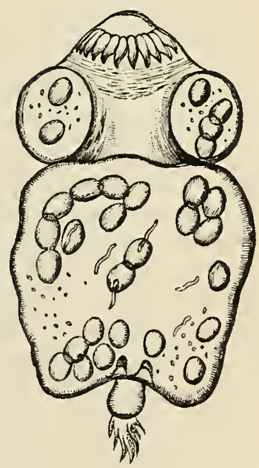
worm, continues to live until the ova are expelled, it is an intermediate state. The scolex or head is a kind of nurse; it is asexual and buds metameres, which are reproductive. The eggs produced within each of the metameres are numerous and too large to escape, except by rupturing the tissues; they may escape from the host, included in the metamere when this becomes separated, and the escape may be with the evacuations of the animal, or the metamere may move out by its own activity. Under both circumstances the metamere has a power of independent movement, and creeps slowly from the dung on to all kinds of moist substances, such as stalks of grass, leaves, and vegetables. In this case they are eaten, with the vegetable matters, by vertebrates. Sometimes the metamere falls into water, where it bursts, and the eggs are cast forth and are drunk by animals. Arrived in the stomach of their new host, the metameres are more or less digested, and the eggs are diffused there, or sometimes imperfect digestion may occur, and the brood may reach the small intestine. In some instances the eggs may be set free in the host by rupturing the metameres, and if they are then expelled there is a chance of their being eaten or drunken and getting into the stomach and intestine of a second host. The so-called eggs have tough shells, and the embryos within are totally unlike their parents. They are globular naked vesicles, the largest being 0·05 of a millimetre in length; they have a cuticle, and either six, or four, microscopic hooklets on their anterior extremity, with which they will, if they have the opportunity, bore inwards into the tissues of their future host.

These embryos are capable of motion, and under the influence of warmth and nourishing juices around them begin to migrate. Each brings the central pair of hooklets together like a wedge, and thrusts and twists them into the mucous membrane of its host. The other hooks move backwards, and finally the parasite reaches a small vein belonging to the portal system. By the flow of blood it is carried into the liver and can go no farther. Or it may get into other blood-vessels and be carried into the general circulation, and be deposited at last in some organ, such as the brain or in the skin. The little vesicle with its hooks may grow in the blood-vessel, which may form a cyst around it, or the parasite may penetrate the vessel and get into the tissues of the body, and a cyst will enclose it there.

Then a new growth occurs within the vesicles, and by a process somewhat similar to budding, one or numerous bodies resembling the heads (or scolex) of a Tape Worm are developed. These, if they escape by the death of the animal, or by its being eaten by others, will become Tape Worms in the devourer. Thus the mouse, eating dirty substances, gets an embryo into its body, and the cat eats mouse and embryo; and the new growths within the last escape as the mouse is digested, and produce Tape Worm in the cat. Or the part of the embryo which is covered with the hooks becomes developed into a larger body, and has suckers and hooks differently arranged.

The embryo from the egg, which thus becomes encysted in the tissues of a vertebrate animal, is termed then a Cysticercus, and it forms one stage of a disease producing "measles" in pork, for instance. The Cysticercus being swallowed by another vertebrate, the fore part of it, or the scolex, becomes the head or a sexual part of a Tape Worm. Sometimes the cyst of the embryo grows to a considerable size, and then the scolices which bud from its inside are called Echinococci, and the cyst is a hydatid.

These Echinococci are, however, the product of a Tape Worm which infests the dog and wolf, and the eggs, by some means or other, are swallowed by men and animals and develop the truly dangerous hydatid disease of the liver and other organs. This Tape Worm belongs to the genus Tænia and to the species *T. Echinococcus.*



HEAD OF ECHINOCOCCUS.
(After Huxley.)

Another species of Tænia, or Tape Worm, which is the Beef Tape Worm,* has the head without any coronet of hooks. It varies from fifteen to twenty-three feet in length, and the metameres, some hundreds in number, have the sexual organs fully developed in the 450th. The Cysticercus of this worm forms measles in oxen, and the scolex of course has no hooks. The Beef Worm is found in man, and calculations have shown that it may

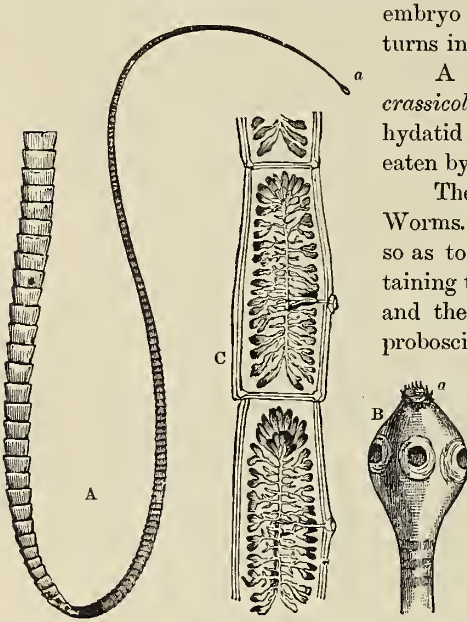
* *Tænia mediacanellata.*

grow at the rate of seventy-two millimetres a day, and that thirteen metameres may be produced in the same time.

The common Pork Tape Worm,* common in the intestines of man, looks like a long, soft, white, jointed thing, which, when alive, elongates and contracts readily. The scolex, or head, is armed with hooks and suckers, and the metameres present water channels, one on each side, and joined above and below, besides egg glands and a uterus centrally placed and branching, and also the male elements. The embryo scolex forms the pork measle, and, being eaten by man, turns into the common Tape Worm of the intestines.

A Cysticercus lives in the mouse, and it produces *Tænia crassicolla* in the cat. The cause of the death of many sheep is a hydatid in the brain, called *Cœnurus cerebralis,* and this, when eaten by the dog, produces *Tænia cœnurus* in its intestines.

The genus Bothriocephalus contains foreign and Irish Tape Worms. Its segments or metameres do not separate individually so as to become independent organisms. It is a broad worm, attaining twenty-five to seventy feet in length and an inch in breadth, and there may be 4,000 joints. In the genus Tetrarhynchus four proboscis-like tentacles exist, thickly set with hooklets, retracted near the suckers. The shorter Tape Worms, (genus Caryophyllus) do not have the metameres separable, and the head, or scolex, produces one only, which carries the reproductive organs.



THE TAPE WORM.

A, a, a piece of Tape Worm with small head and metameres gradually increasing in size; B, a, head with suckers and hooks; C, metameres with ovarian apparatus.

ORDER TREMATODA.

These worms, many of which are called Flukes, are flat, rarely cylindrical, often bladder-like, broad, elongated creatures; they are not jointed, and are frequently leaf-shaped, and they have no vent.

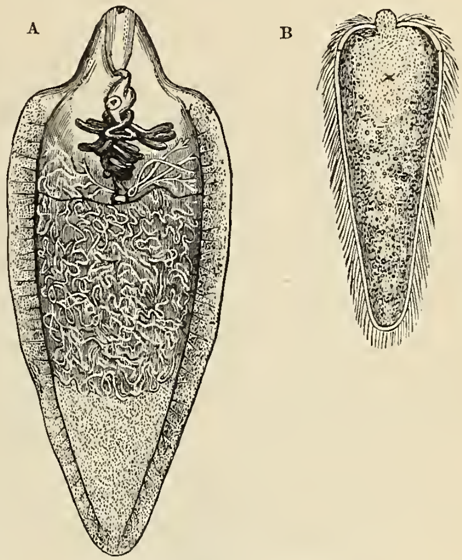
The Trematoda are parasitic within or outside animals, and whilst some grow from large eggs, laid about the localities frequented by the parent, into the shape of the adult, others present the phenomena of alternation of generation, complicated by curious metamorphoses. These last kinds come from very small eggs which have got into water or damp places, and are at first very minute, contractile embryos, sometimes ciliated, and which endeavour to settle on some animal or other, ordinarily some of the Mollusca. This stage is that of the ciliated embryo. The ciliated embryo's office is to get on to a host; it then loses its cilia and becomes stationary on its host, and then gives exit to a cylindrical sac-like object, which has two lateral prolongations close to a tapering tail. At this stage of growth the parasite is called the *Redia*, and it has a mouth and a simple intestine, but no other organs. Within this bag-like Redia a process of budding goes on, each bud becoming a creature like the parent of the ciliated embryo in shape; but it is destitute of reproductive organs, and is furnished with a long flat tail like a Tadpole, by which it is propelled after the escape from the Redia. At this stage they are called Cercariæ. They burst forth, and, after a free-swimming existence, penetrate the body of some animal. They drop their tails and become encysted in the tissues. Finally, they assume the adult form and develop reproductive organs within, out of which pass the eggs. The Redia acts as the "nurse," and the Trematode may pass through life by inhabiting two very different animals, after coming forth from that inhabited by the parent. The stages vary in different genera, and, as a rule, the first are passed in invertebrate and the last in vertebrate animals.

The first sub-order of the Trematoda is that of the Distoma, with not more than two suckers without hooks, and their Rediæ and Cercariæ live principally in Mollusca.

Distoma hepaticum and D. lanceolatum are species which have been found in the human liver. The first-named species also bears the generic title Fasciola, and is very common in the Ruminantia, and it

* *Tænia solium.*

produces the "rot." The effects of allowing flocks of sheep to graze on low pastures, during continuous wet weather, are unfortunately too well known. The animals take in the parasite with their grass, or accidentally consume Mollusca which contain them.



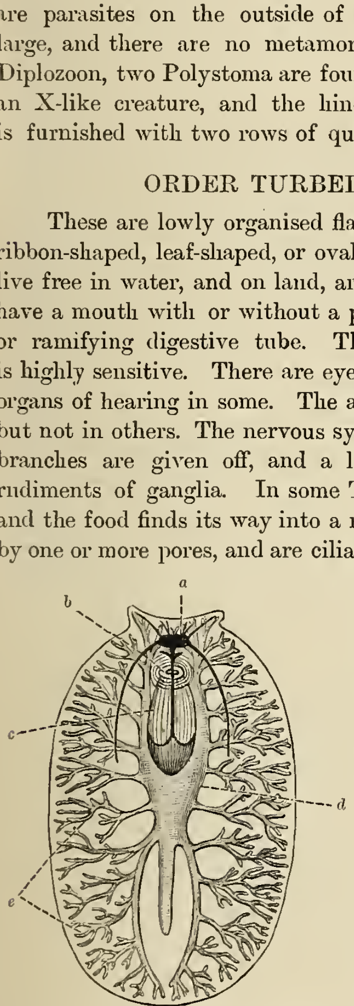
DEVELOPMENT OF LIVER FLUKE.
A, sexually mature (*after Blanchard*); B, embryo (*after Leuckart*).

In the genus Amphistomum the ventral sucker is close to the posterior end, and is deep. The species are found in the frog, ox, elephant, and many other animals.

The next sub-order or division of the Trematoda is that of the Polystoma, which are furnished with several suckers, the hindmost of which often have hooks. They are parasites on the outside of animals. The eggs are large, and there are no metamorphoses as a rule. In Diplozoon, two Polystoma are found united so as to form an X-like creature, and the hinder extremity of each is furnished with two rows of quadruple suckers.

ORDER TURBELLARIA.

These are lowly organised flat worms, which may be ribbon-shaped, leaf-shaped, or oval, broad, or long. They live free in water, and on land, are predaceous, and they have a mouth with or without a proboscis, and a simple or ramifying digestive tube. The skin is ciliated, and is highly sensitive. There are eye-spots and rudimentary organs of hearing in some. The anus is present in some, but not in others. The nervous system consists of two ganglia placed in the anterior part of the body; branches are given off, and a longitudinal cord extends backwards, and in some there are the rudiments of ganglia. In some Turbellaria the limits of the digestive tract are not distinguishable, and the food finds its way into a mass of internal cells. All have water-vessels which open externally by one or more pores, and are ciliated; and also "pseudo-hæmal" vessels, consisting usually of a median, dorsal, and two lateral trunks, which unite in front and behind. The walls of these vessels are contractile, non-ciliated, and their contents are clear and uncoloured. One sub-order, the Nemertina, has ciliated grooves on the anterior part of the body, on the floor of which is a nervous structure. In most the embryo passes by insensible gradations into the form of the adult, and in some there is a metamorphosis. There are three sub-orders, the Rhabdocœla, the Dendrocœla, and the Nemertina or Rhynchocœla.



DIGESTIVE APPARATUS OF EURYLEPTA SANGUINOLENTA.
a, nervous ganglion, or brain; *b*, mouth; *c*, pharynx; *d*, stomach; *e*, ramification of the digestive cavity.

The Rhabdocœla are the simplest forms, and have a flat body with cylindrical or rod-shaped digestive organs, without a vent. They are carnivorous and suck the juice of small worms and entomostraca and insect larvæ which they envelop in a secretion. One family, the Opistomidæ, has a proboscis, coloured eyes, and calcareous particles connected with hearing. The family Convolutidæ are long flat worms with chlorophyll in their tissues, and one of the species is a very active dweller between tide-marks in England. It swims well, yet it has no special senses. The Dendrocœla have a ramified intestine, and the long flat body has a proboscis. The Land Planarians have eyes, no tentacles, a proboscis, and a narrow body. They are found in the United Kingdom and generally in Western and Central Europe. They have been found in America, and on continental as well as on oceanic islands. Moseley states that they are nocturnal in their habits, and shun the light, getting under leaves. Some contain chlorophyll, and seek the light but die in the sunshine. They eat small snails, worms, and flies. An American kind secretes a mucous thread and suspends itself in the water, and another

lets itself down from the leaves by one. The Marine Planaria are found swimming in an undulating manner on the surface of the ocean, where they seem to live free. Darwin described one in 1844. Moseley describes them, in the East Indian Archipelago, as swimming in a lively manner. Others collect on the Gulf Weed; such are the Stylochidæ, which have two small tentacles with eyes on them and on the head also. They swim in a rapid sinuous manner, and attack their prey at once. In this group the young undergo a metamorphosis, and in one stage greatly resemble a Rotifer.

The Nemertina are long, worm-like, proboscis-bearing, and marine; they have brittle bodies and a straight intestine with lateral cæca. The body is very extensile, and they live under stones, avoid light, and hunt their prey.

The Sea Long Worm (*Lineus longissimus*) is fourteen feet long and only two to four lines broad. The eggs of these give forth ciliated embryos, and they grow into a helmet-shaped body with a tuft of cilia. Certain cells enclose the digestive canal and give rise to a worm-shaped body—the future adult form. This fact links the group to the Echinoderms.

Worms lived in the geological ages, and certain markings in the old rocks are attributed to them. Trails and tracks of the Errantia, such as are termed Nereites and Phyllodocites, are found in the Silurian rocks. The horny jaws of the Errant Annelida have been found in the Paleozoic formations, and largely in the upper Silurian of Wenlock. Burrows of worms occur in the Cambrian and Silurian age, such as Scolithes and Arenicolites, and the casts or the fæcal matters of Annelida, are frequent in many rocks. Tubicolar Annelida of the extinct genera Cornulites, Ortonia, Serpulites Spirorbis, Serpula, &c., are found from the Silurian to the latest geological deposits, but the genera usually became extinct with time, the last two still existing.

CLASSIFICATION.

TYPE VERMES.

Class Annelida	Sub-class Chætopoda	Order Oligochæta. „ Polychæta.
	„ Hirudinea	
„ Gephyrea		„ Gephyrea Inermia. „ „ Armata. „ „ Tubicola.
„ Rotifera		Family Philodinidæ. „ Brachionidæ. „ Hydatineæ. „ Floscularidæ.
„ Nemathelmintha		Order Nematoidea. „ Chætognatha.
„ Plathelmintha		„ Cestoida. „ Trematoda. „ Turbellaria.

P. Martin Duncan.

THE PRICKLY-SKINNED ANIMALS (ECHINODERMATA).

Position of the *Echinodermata* in the Animal Kingdom—Characters distinguishing them from the other *Radiata*—Subdivisions of the Group—The Limestone Skeleton: its Various Forms—The Digestive Tube—The Nervous System—The Blood-vascular System—The Water-vascular System—The Body-cavity and its Contained Corpuscles—The Various Forms of Echinoderm-larvæ—Direct Development of some Echinoderms in the Southern Sea—Distribution of the Group in Space and Time—The *Echinozoa*—Structure and Habits of Starfishes, Ophiurids, Urchins, and Holothurians—The Trepang-fisheries of the Tropical Seas—The *Crinoidea*—Structure and Mode of Life of a Feather-star—The Palæozoic Crinoids, Cystids, and Blastoids.

THE Marine Invertebrata known as *Echinodermata** owe their name to the prickly nature of their skin, which is usually more or less thickly set with spines and granules of limestone. Such animals are the Sea-urchins, or Sea-hedgehogs (Fig. 14), the Starfishes (Fig. 1), Sand-stars, Brittle-stars (Fig. 11), Feather-stars (Fig. 19), Sea-lilies (Fig. 18), and the Sea-cucumbers (Fig. 17).

The Echinoderms constitute one of the three great groups of animals which were associated by Cuvier under the name *Radiata*. The especial characteristic of this division of the animal kingdom is the arrangement of the various organs of the body in a radiating manner around a central axis, in which the mouth is placed. The bilateral symmetry, so apparent in the *Articulata* and in the bivalve *Mollusca*, is not visible at first sight in such animals as a Starfish, a Sea-anemone, or a Jelly-fish. The younger stages of all these creatures, however, exhibit a more or less evident bilateral symmetry (Figs. 2–5, 7); and this is sometimes quite distinct in the adult animal (Figs. 1, 11, 14, 19), for a median plane can be found, with the parts of the body which lie on either side of it disposed symmetrically in relation to it. The body of an Echinoderm is also far more complicated in its structure than that of a Polype, or Jelly-fish. The digestive apparatus is entirely shut off from the body-cavity, and there are two separate systems of vessels ramifying through the body, which are either completely independent of the body-cavity, or only communicate with it by special openings.

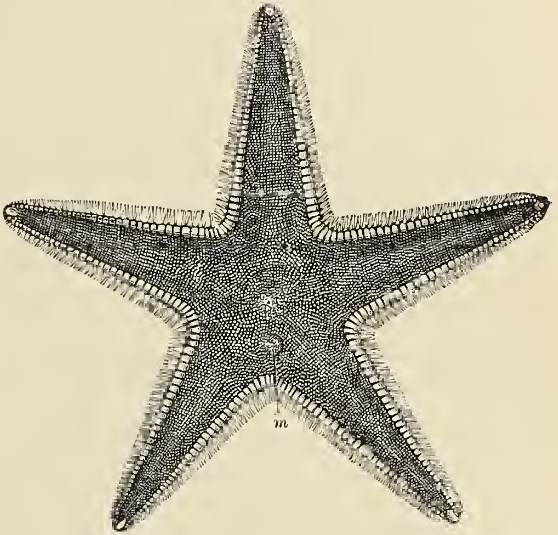


Fig. 1.—ASTROPECTEN IRREGULARIS, A COMMON BRITISH STAR-FISH, SLIGHTLY REDUCED.
m, the madreporite.

On account of these and other striking features in their organisation, the Echinoderms were removed from the Radiate type by Leuckart, a proceeding which has met with almost unanimous acceptance among European naturalists. But the resemblance between Echinoderm larvæ and young *Ctenophora* is adduced as one amongst other reasons (by some American zoologists) for affirming that the type of Radiates constitutes an independent division of the animal kingdom, containing three equivalent classes—Echinoderms, Jelly-fishes, and Polypes.

On the other hand, there are considerable resemblances between certain Echinoderms, both larval and adult, and some of the lower worms; and after Leuckart's removal of the former from the Radiate type, they were thrown, together with the Wheel-animalcules, Tape Worms, Fluke Worms, &c., into one group—the *Annuloida*,† the name of which indicated the worm-like (Annelidan) affinities of some of its members.

Further investigation has shown, however, that this arrangement is not a satisfactory one, and at the present time the Echinoderms are regarded by most zoologists as forming a distinct primary division of the animal kingdom. Its chief subdivisions are indicated in the following Table.

* Greek, *echinos*, hedgehog; *derma*, skin. † Latin, *annulus*, a ring; Greek, *eidos*, form.

SUB-KINGDOM ECHINODERMATA.

	Class	Order.	Genera.
Echinozoa	* Asteroidea	†	Astropecten, Solaster, Goniaster.
	* Ophiuroidea	Ophiurida	Ophiura, Ophiocoma, Ophiothrix.
		Astrophytida	Astrophyton, Gorgonocephalus, Euryale.
	Echinoidea	*Palæchinoidea*	*Palæchinus, Archæocidaris, Melonites.*
		Desmosticha	Echinus, Cidaris, Asthenosoma.
		Clypeastrida	Clypeaster, Mellita, Echinocyamus.
		Petalosticha	Spatangus, Brissus, Pourtalesia.
	Holothuroidea	Apoda	Synapta, Chirodota, Molpadia.
		Pedata	Holothuria, Cucumaria, Psolus.
		Elasmopoda	Elpidia, Deima, Ilyodæmon.
Pelmatozoa	Crinoidea	*Palæocrinoidea*	*Actinocrinus, Cyathocrinus, Platycrinus.*
		Neocrinoidea	Pentacrinus, Comatula, *Apiocrinus.*
	Cystoidea		*Glyptosphærites, Echinosphærites, Caryocrinus.*
	Blastoidea		*Pentremites, Granatocrinus, Codaster.*

The names of orders and genera which are extinct are printed in italics.

Exclusively marine animals, the Echinoderms remove limestone from its solution in the sea-water, and build it up into a skeleton of very varied shape and of very different degrees of complexity. This skeleton is least developed in the Sea-cucumbers, or *Holothuroidea*‡ (Fig. 17). The skin of these animals is very tough and leathery, with little limestone plates scattered about on it. Occasionally, however, the plates are more developed, and overlap one another so as to form a continuous covering all over the body (*Psolus*). Certain Sea-urchins (*Echinoidea*§) are also in the same condition, the body retaining its flexibility, but being at the same time protected from injury by its coat of mail (*Asthenosoma*‖). In most of the Urchins, however, the body is enclosed in a shell, or "test," which is composed of numerous limestone plates, firmly united to one another by their edges, and supporting spines of the same substance (Figs. 14—16). Besides this external skeleton, there is also more or less of an internal skeleton, in the form of arched plates, pillars, or radiating partitions within the test. Five pairs of arched plates, which are known as *auriculæ*¶ (Fig. 15), are of especial importance, as they occupy a very definite position with regard to the vascular trunks that radiate from the oral centre. In the Starfishes and Brittle-stars they are represented by a double series of more or less arched limestone pieces, which form an internal skeleton in each arm, and are called the ambulacral ossicles (Figs. 9, 13, *ao*). The skeleton of an Urchin, then, is almost entirely external, while that of the Starfishes and Brittle-stars is chiefly internal; but in both these classes, and especially in the latter, there is also an external skeleton of limestone plates, which bears spines, and is sometimes very considerably developed (Figs. 9, 11). Yet another form of skeleton is met with among the Crinoids.** The successive joints which make up the arms of a Sea-lily (Fig. 18; Fig. 20, *Br.*), although practically external, are of a different nature from the pieces forming the test of an Urchin (Fig. 14), for they occupy an exactly contrary position with respect to the vascular systems. Neither do they correspond to the ambulacral ossicles of a Starfish-arm (Fig. 9, *ao*), although these, together with the test of the Urchin, are not altogether unrepresented in the Crinoids.

The digestive tube of all Echinoderms is distinct from the general cavity of the body. It may be of considerable relative length, and make complicated windings within this cavity, as in the Urchins, Holothurians, and Crinoids (Fig. 16, *i*; Fig. 20, G); or it may be a short bag, without any other opening than the wide mouth, as in the Ophiurids†† (Fig. 12); or lastly, there may be a short and straight tube in the vertical axis of the body, with lateral extensions into the arms (Fig. 9, *pc*), as in the Starfishes.

The nervous system consists of an oral ring (Figs. 12, 20, *nr*), from which radiating cords proceed along the primary divisions of the body (Figs. 9, 12, 13, 21, *n*). Both the ring and the radial nerves originating in it are in very close relation to the cellular covering of the oral surface of the body, which is specially modified where the nervous tissue underlies it. This tissue consists of closely packed fibrils and minute cells connected with them; but there is no special arrangement of

* For convenience of reference these two groups together are often spoken of as the Stellerida.

† A good classification of the Asteroidea is still a *desideratum*.

‡ Greek, *holothourion*; *eidos*, form.

§ Greek, *echinos*, hedgehog; *eidos*, form.

‖ Greek, *asthenes*, weak; *soma*, body.

¶ Latin, diminutive of *auris*, ear.

** Greek, *krinon*, a lily; *eidos*, form.

†† Greek, *ophis*, a snake; *oura*, a tail; *eidos*, form.

the latter into ganglia, the minute structure of the oral ring being identical with that of its radial extensions. But although anatomical investigation fails to reveal the presence of a brain, or even of a ganglion, yet the result of physiological research is to indicate that the oral nervous ring is the seat of a centralising influence, which proceeds outwards from it, and regulates the movements of the tube-feet—organs of which more or less use is made in locomotion.

Immediately within the oral nervous ring is an annular blood-vessel (Figs. 10, 12, 20, *ob*), from which radiating trunks extend (Figs. 9, 10, 12, 13, 21, *b*). It is connected with a more or less complicated network of vessels, which surrounds the digestive apparatus (Fig. 20, *ib*). In most Echinozoa* it also communicates, by means of a bundle of vessels that run nearly in the vertical axis of the body (Fig. 10, *cp*), with an aboral blood-vascular ring (Figs. 10, 12, *ab*), from which vessels (Fig. 10, *gv*) proceed to the generative organs. This vascular bundle (Fig. 10, *cp*) was formerly regarded as a heart, and has been described as performing rhythmical contractions. This, however, is very doubtful ; while some authors go so far as to say that the organ in question is merely a gland with an excretory duct, which opens upon the aboral surface of the body, and is unconnected with any portion of the vascular system.†

The special feature in the anatomy of the Echinoderms is a set of tubes which communicate with the exterior, and serve the purposes both of respiration and of locomotion. It is known as the water-vascular system, and consists of an oral ring (Figs. 12, 20, *wr*) and radial extensions (Figs. 9, 12, 13, 20, *w*), like those of the blood-vascular system, which lies immediately external to it. The radial vessels give off numerous lateral branches, which enter contractile processes of the body-wall, the tube-feet, or tentacles. In the Crinoids, which lie on their backs, with their mouths upwards, the tentacles are exclusively respiratory in function. But most of the Echinozoa live mouth downwards, and the tube-feet are used in locomotion. They are, in consequence, often spoken of as "the ambulacral‡ feet," while the whole system of water-vessels is called the ambulacral system. In most Echinozoa its communication with the exterior is effected by a tube which starts from the water-vascular ring, and opens on the surface of the body by a sieve-like plate, the "madreporite"§ (Fig. 1, *m*). This water-tube, as we will call it, is sometimes known as the sand-canal, or stone-canal, on account of the limestone deposits in its walls. It lies close to the central plexus, and is bound up together with it in the same membranous sheath.

In most Holothurians and in the Crinoids there are one or more tubes depending from the water-vascular ring, and opening into the body-cavity, which communicates directly with the exterior (Fig. 20, *wt*); and as far as can be judged from the conflicting statements of different naturalists, these are the only Echinoderms in which there is a direct communication between the body-cavity and the exterior. Protoplasmic corpuscles of different kinds are dispersed in the fluid which it contains. Some resemble the white corpuscles of the blood of a vertebrate animal, while others exhibit more active changes of form, and put out long thread-like extensions of their substance. The body-cavity of an Urchin or Holothurian also contains granular masses, which are coloured with a brown substance that contains iron, and changes its tint under atmospheric influences, so that it is probably connected with the process of breathing. This function, however, is mainly performed by the water-vascular system. It contains minute red corpuscles, tinged with hæmoglobin, the oxygen-carrying material that colours the corpuscles of our own blood, and has also been detected in that of Molluscs, Crustacea, Insects, and Worms. The cilia lining the water-vessels keep up continual currents in their interior, and the circulation of the corpuscles which is due to these currents is increased by the contraction of the walls of the water-vessels, and by the continual motion of the tube-feet or tentacles, whether they be used for locomotion or not.

The sexes are distinct in most Echinoderms, and the fertilised ova generally pass through a complicated process of metamorphosis before assuming their adult form. They are hatched as uniformly ciliated free-swimming embryos, which gradually acquire a digestive tube with two openings. The cilia become restricted to one or more transverse ridges (Fig. 7), and the larva passes

* Greek, *echinos*, hedgehog ; *zoon*, animal.

† These statements are probably erroneous. They are based almost entirely upon the results of injections, which are much less likely to give accurate results than the study of continuous series of thin sections through any organ and the structures connected with it.

‡ Latin, *ambulacrum*, a place for walking. § *Etym.*, pierced with small holes, like the coral known as *madrepore*.

from the spherical condition into one which exhibits a very complete bilateral symmetry. Portions of the primitive digestive tube become cut off from it, and form closed "vaso-peritoneal" cavities (Figs. 2, 4, 6, *w*), which develop into the body-cavity and the water-vascular system of the mature Echinoderm. The latter system acquires a communication with the exterior by a water-tube, which opens on the dorsal surface of the body by a "water-pore" (Figs. 2, 6, *wp*), that eventually becomes the madreporite of the Echinozoa.

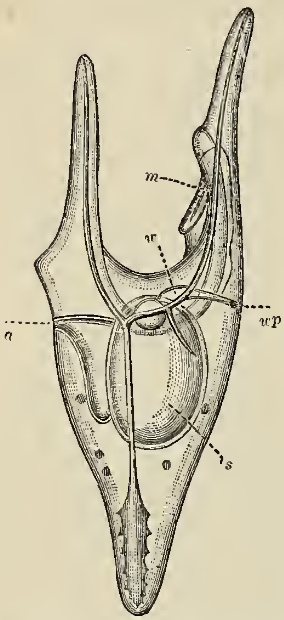


Fig. 2.—PLUTEUS LARVA OF THE PURPLE EGG-URCHIN (*Echinus lividus*), SEEN IN PROFILE.

m, mouth; *a*, anus; *wp*, water-pore, or external opening of the water-tube, which leads into *w*, the rudiment of the water vascular ring. (*After Metschnikoff.*)

The forms assumed by the fully-grown Echinoderm larvæ are very various. In the Urchins (Fig. 2) and Ophiurids (Fig. 3) the dorsal region of the larva is produced into a sort of conical hump, while the ventral face becomes much excavated, and its edges are produced into four pairs of slender processes, or arms, which are symmetrically arranged around the mouth (Fig. 2, *m*). These arms are supported by a framework of limestone rods, which has somewhat the appearance of an inverted painter's easel, and is exclusively characteristic of the Urchins and Ophiurids. It has nothing to do with the skeleton of the mature Echinoderm, coming into existence before this makes its appearance, and disappearing as it attains its full development. The arms open and shut like the ribs of an umbrella during the movements of the larva, which is generally known as a "Pluteus." This name was given to it on account of its ever-changing form, before its real nature was thoroughly understood.

In the Crinoids, on the other hand, a somewhat complicated skeleton makes its appearance at a very early stage of embryonic life, the whole or greater part of which passes directly into the skeleton of the adult. But in the larvæ of Starfishes and Holothurians there is little or no provisional skeleton; and the rudiments of the skeletal system of the adult do not appear till the later stages of larval existence. The two ciliated bands at first encircling the Starfish larva gradually extend themselves, until they enclose nearly the whole of the upper and lower halves of the body, so as to form two large crescentic shields. The larva in this condition exhibits complete bilateral symmetry, and is called "Bipinnaria."* Loops now appear in the outlines of the oral and anal shields, and gradually increase in length, so as to develop into a number of long slender movable arms, which stretch out from the larval body in various directions, bending and twisting in the most graceful manner, as they are not supported by limestone rods (Fig. 4). The continual play of these arms not only assists in the locomotion of the larva, but also produces currents in the water which set towards its mouth. This stage of the Starfish larvæ is known as the "Brachiolaria";† and the development of the adult Echinoderm from it or from a Pluteus takes place entirely at the hinder end of the larval body. Rudiments of tentacles appear on the growing water-vascular ring, which is situated at the left side of the larval stomach, while the first traces of the permanent skeleton show themselves on its right side, near the dorsal pore of the water-vascular system. The remainder of the larval body gradually shrivels up and disappears, its substance going to feed the growing Echinoderm. This is well shown in Fig. 4, which represents a Brachiolaria with the Starfish disc developed at its anal extremity, some of its arms having been already absorbed. A similar process goes on in the case of the Pluteus

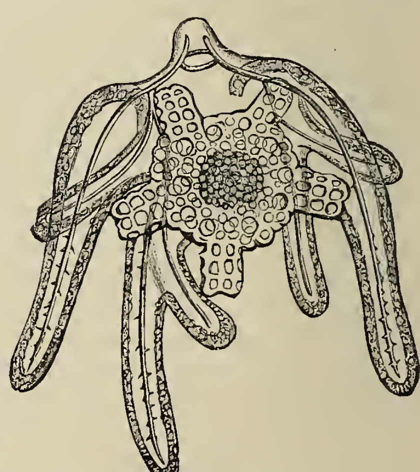


Fig. 3.—*Pluteus paradoxus*, THE ADVANCED LARVA OF AN OPHIURID, WHICH CONTAINS THE RUDIMENTS OF THE DISC AND RADIAL SKELETON OF THE ADULT, TOGETHER WITH THE LIMESTONE FRAMEWORK THAT SUPPORTS THE ARMS OF THE PLUTEUS. (*After J. Müller.*)

* Latin, *bis*, twice; *pinna*, a feather. † Latin, *brachiolum*, diminutive of *brachium*, an arm.

larvæ (Figs. 2 and 3). The young Urchin or Ophiuran gradually encroaches upon the Pluteus to such an extent that it forms an essential part of the body, the arms and rods seeming to be mere appendages, which ultimately disappear altogether.

The development of the young Holothurian from its larva is much simpler than that of the other Echinozoa. There is but one continuous longitudinal ciliated band around the bilateral larva (Figs. 5, 6, *c*), instead of two, as in Bipinnaria; and this does not throw out long processes, but only becomes deeply sinuated. Certain parts of the sinuated portions of opposite sides become united together, while others are obliterated, so that the larva, which has become barrel-shaped, is surrounded by a number of transverse ciliated rings. These in their turn disappear, the body of the larva elongates, and tentacles appear round the mouth, while the water-tube usually loses its connection with the exterior by the dorsal pore (Fig. 6, *wp*), and depends freely from the water-vascular ring into the body-cavity, into which it opens. But the amount of metamorphosis which the larva undergoes is not considerable, as it has no appendages to be resorbed into the body of the adult.

Fig. 4. — SIDE VIEW OF THE ADVANCED BRACHIOLARIA LARVA OF A STARFISH (*Asterias vulgaris*).

The whole of the terminal anal part of the larva has been absorbed into the disc of the growing Starfish (*r*), the oral extremity alone, with its adjacent arms, retaining its original shape. *w*, one of the vaso-peritoneal tubes, from which the body-cavity and the water-vascular system are developed. (*After A. Agassiz.*)

There is still less metamorphosis in the development of a Crinoid. The cilia, which appear at first over the whole surface of the embryo, become restricted, before it is hatched, to four transverse bands and a tuft at its hinder end (Fig. 7), while the embryo becomes slightly curved, somewhat like a kidney-bean. In its concave surface, which is turned downwards, is the single opening of its digestive canal, corresponding to the anus of a Bipinnaria. The larva gradually increases in length, and delicate limestone plates make their appearance near its front end, arranged in two cross-rings of five plates each. The plates of the lower ring, which are called the basals, rest upon the top joint of a short stem, composed of delicate rings of limestone. At this stage the larva has the form of a bent club or rod, with an enlarged head, which becomes the body of the future Crinoid. The permanent mouth appears in the centre of the upper ring of plates, which are consequently termed the "orals." They are gradually carried away from the cup formed by the basals by the appearance, between the two rings of plates, of the rudiments of the arms, which grow outwards as rapidly elongating processes. The advanced Crinoid larva is known as a "Pentacrinoid" (Fig. 8, B), owing to its resemblance to *Pentacrinus*,* one of the Sea-lilies. The development of a Crinoid is thus much more direct than that of a Starfish or Urchin. There is no metamorphosis, and either the whole of the larval body passes directly into the adult, or the stem is discarded, and the cup with the arms attached leads an independent existence. This is the case with the Feather-star (Fig. 19), which separates itself from all but the top joint of its stem, and anchors itself by little clawed hooks, or cirri, that appear upon this joint (Fig. 8, B; Fig. 20, *ci*).

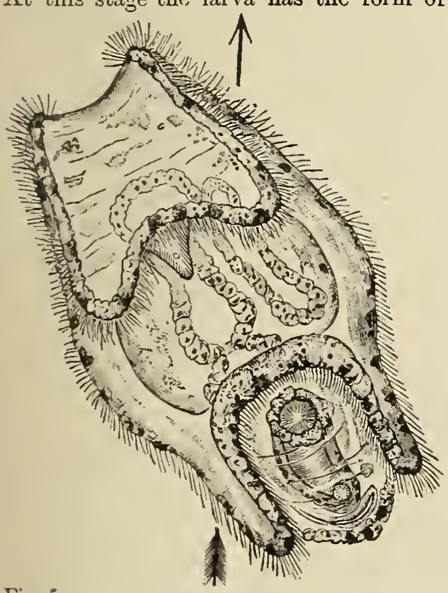


Fig. 5.—LARVA OF HOLOTHURIA TUBULOSA IN ITS NATURAL POSITION.

The arrow indicates the axis of rotation. The mouth at the upper and the anus at the lower end are connected by a short digestive tube, on the upper side of which is seen the rudimentary water-vascular ring. The cilia are arranged in a sinuated band. (*After Selenka.*)

A still more direct mode of development occurs among most of the Echinozoa of the Southern and sub-arctic Seas, which produce no free-swimming ciliated embryos at all. But the young develop directly, either within or upon the body of the parent, where they are protected until sufficiently advanced to look after themselves. In Urchins, Starfishes, and some Holothurians, the nursery or brood-pouch is outside the body of the parent. In some Urchins, for example, a kind of open tent is formed in the neighbourhood of either mouth or anus by the approximation of two or three rows of spines. In

* Greek, *pente*, five; *krinon*, lily.

a large Starfish dredged by the *Challenger* in the Southern Seas, a sort of tent is formed in the middle of the upper surface of the body, which consists of five membranous valves supported by spines. These valves can be raised or drawn together so as to form a low pyramid; and the eggs pass directly from the ovaries into its cavity, where they assume the form of young Starfishes, without previously passing through the Bipinnaria and Brachiolaria stages. In another species the spines covering the back have flattened heads, which fit closely together, so as to cover in the arcade-like spaces left between their shafts. The young develop within these spaces, eventually pushing their way out by forcing the spines aside. A similar nursery is formed on the back of a South Sea Holothurian (*Psolus*) by the apposition of the heads of mushroom-shaped plates; while in another species from the Falkland Islands there is no special nursery, but the young come to be packed into two continuous fringes adhering to the two rows of tube-feet along the back, which are imperfectly developed, and are not used for locomotion. In one South American Holothurian, however, the young are protected within the body of the mother, one individual having yielded sixteen young ones measuring $\frac{1}{25}''$ in length. In the viviparous Ophiurids, the nursery, though internal, is not a portion of the body-cavity, but a pouch which opens externally and projects into the body-cavity, serving also at the same time as a breathing apparatus. There are usually ten of these pouches, though as many as fourteen have been found in one individual, each containing three young Brittle-stars.

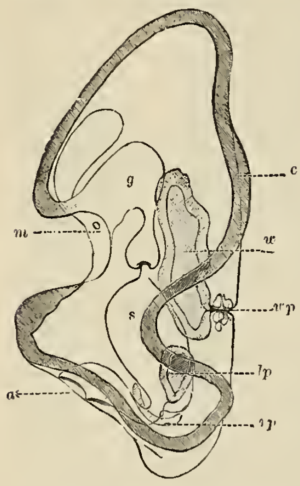


Fig. 6.—DIAGRAM OF A SIDE VIEW OF THE HOLOTHURIAN LARVA REPRESENTED IN FIG. 5.

m, mouth; *g*, gullet; *s*, stomach; *a*, anus; *c*, longitudinal ciliated band; *w*, rudiment of water-vascular ring; *wp*, water pore; *rp*, *lp*, right and left peritoneal cavities, from which the water-vascular system is developed. (*After Selenka.*)

Echinoderms are to be found in all parts of the ocean, whether in polar, tropical, or temperate regions, but they are most varied and, on the whole, most abundant in the shallower waters of the tropical seas. They have also a wide bathymetrical range, extending from between tide-marks to some of the greatest depths explored by the dredge, where they are chiefly represented by the Ophiurids. There are certain forms in each class which are especially characteristic of the abyssal depths, and have a very extensive distribution. Thus most deep-sea Holothurians belong to a very remarkable section of the group, the *Elasmopoda*,* which look singularly like nudibranchiate Mollusca. The Stalked Crinoids are also characteristic of the greater depths, some of them being the last survivors of a large and important group (*Apiocrinus*†) which flourished in the Mesozoic Seas. Similarly, the more prominent abyssal forms among the Sea-urchins are chiefly those which have a flexible test (*Asthenosoma*), instead of a shell of immovable plates. They belong to a very singular group, which was believed to have become extinct after the deposition of the white chalk. Among the Starfishes and Ophiurids, again, the same generic types inhabit the great ocean depths in all parts of the world; but they are not so interesting in their palæontological relations as the Stalked Crinoids and the flexible Urchins.

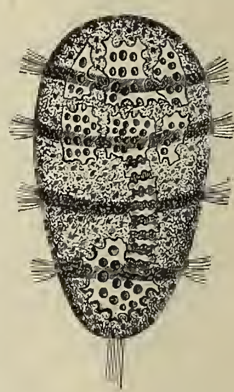


Fig. 7.—DORSAL VIEW OF THE LARVA OF THE ROSY FEATHER-STAR (COMATULA ROSACEA) SHORTLY BEFORE THE DISAPPEARANCE OF THE CILIATED BANDS. MAGNIFIED TWENTY TIMES. (*After Wyville-Thomson.*)

Fossil Echinoderms occur in most of the stratified rocks from the Upper Cambrian upwards. Certain Palæozoic limestone beds are almost exclusively composed of crinoidal remains. The Stalked Crinoids were most abundant during the Palæozoic period, during which the Cystids‡ and Blastoids§ also flourished, to become extinct at or before its close. But the free Crinoids (*Comatula*||) are probably more abundant at the present time than in any previous geological period. Starfishes are among the earliest known Echinoderms, and appear to have gone on increasing in importance from the Cambro-Silurian period until the present day. Little is known of the fossil

* Greek, *elauno*, to move; *pous*, foot. † Greek, *apion*, a pear; *krinon*, a lily.

‡ Greek, *kustis*, a bladder; *eidos*, form. § Greek, *blastos*, a bud; *eidos*, form.

|| Latin, *coma*, hair; and the obsolete form, *tulo*, I bear.

Ophiurids, which commence with the same period. The Urchins are represented in the Lower Silurian by a single aberrant form, but more appear in the later Palæozoic beds; while the Mesozoic and Tertiary rocks contain a great variety of types. Fossil remains of the soft-bodied Holothurians are naturally rare, but they can be traced as far back as the Carboniferous period.

The Echinoderms fall into two very natural groups: viz., (1) the *Echinozoa*, including the Urchins, Stellerids,* and Holothurians, all of which crawl about by the aid of their tube-feet, with the mouth downwards or at one end of the elongated body; and (2) the *Pelmatozoa*,† or Stalked Echinoderms. In the latter group the dorsal region of the body is produced into a stalk, by which the animal fixes itself with its oral surface upwards (Figs. 8, 18). In the Feather-stars, which form the majority of recent Crinoids, the stalked condition is a temporary one (Fig. 8), the body eventually detaching itself from the larval stem, and settling down on its own account, though still in the same relative position, *i.e.*, with its oral surface upwards (Fig. 19). Nearly all the fossil Crinoids were stalked, as were also the extinct *Blastoidea* and *Cystoidea*, though a few sessile forms are known.

Fig. 8.—PENTACRINOID LARVA OF THE ROSY FEATHER-STAR (*Comatula rosacea*).

A, quite young, before the opening of the cup and the appearance of the radial plates; B, nearly mature with five cirri upon the top stem joint; *b*, basals; *o*, orals; *r*, first radials.

Among the *Echinozoa*, the Stellerids are those of which the anatomy is most completely known; and as the members of the two classes to which this name is applied resemble one another in very many respects, it will be convenient to take them as the starting-point of our investigations into Echinoderm structure.

(1) *Asteroidea*.‡ The body of a Starfish is usually somewhat flattened, and either pentagonal in outline or more or less stellate, in which case it is said to consist of a central disc extended into five or more arms (Fig. 1). Its shape is maintained by an internal skeleton of limestone joints (Fig. 9, *ao*). This is covered, though not closely, by a tough leathery skin, in which are imbedded granules and plates of limestone, many of them bearing spines. Some of the spines, which are known as paxillæ, assume the form of a stem with an expanded brush-like end (Fig. 9, *pax*). The mouth occupies the centre of the under surface of the body, and a deep groove, the "ambulacral groove," proceeds from it along each of the arms (Fig. 9, *ag*). This groove is nearly filled with the tube-feet, or tentacles (Fig. 9, *t*), which are connected with the ambulacral or water-vessel, situated in the middle line of the arm (Fig. 9, *w*), and are largely used in locomotion. Appended to each of the lateral branches of the water-vessel that proceed to the tube-feet is a minute muscular water-sac, or ampulla,§ by the contraction of which water is driven into the tube-foot so as to expand it. The tube-feet themselves are also contractile, and when several of them which are attached to any object by their terminal suckers are made to contract, the result is that the body is slowly drawn towards the fixed point. Other tube-feet are then distended and projected forwards, to take fresh hold farther on, while those previously fixed are detached by water entering them from the ampullæ, and so the movement goes on. The radial water-vessels all communicate with an oral ring provided with water-sacs, the "Polian vesicles,"‖ which are similar to those in the arms, but do the same work on a larger scale. They are attached to the water-vascular ring between the origins of the radial trunks; and the single water-tube which communicates with the exterior by the madreporic plate (Fig. 1, *m*) occupies a similar interradial position. It is enclosed in a common sheath with the central plexus of the blood-vascular system (Fig. 10, *cp*), which unites the oral blood-vascular ring (*ob*) with the aboral ring (*ab*), connecting the ten genital and the two gastric vessels (*gv*; *pb*). Radial trunks (Figs. 9, 10, *b*) proceed outwards from the oral ring beneath the water-vessels, and send minute

* Latin, *stella*, a star; Greek, *eidos*, form.

† Greek, *pelma*, a stalk; *zoon*, animal.

‡ Greek, *aster*, a star; *eidos*, form.

§ Latin, *ampulla*, a flask.

‖ Named after Poli, the anatomist who discovered them.

branches to the successive tube-feet (Fig. 10, *b f*). External to the blood-vessels are the radial nerves (Fig. 9, *n*), communicating with an oral nervous ring, and sending off very minute tentacular branches. Each nerve terminates at the bent-up extremity of the arm in a pigmented spot, containing clear lens-like bodies, and serving as an eye. Close to it is the terminal tentacle of the arm, which has no sucker, but is excessively sensitive, and appears to be a very delicate organ of touch.

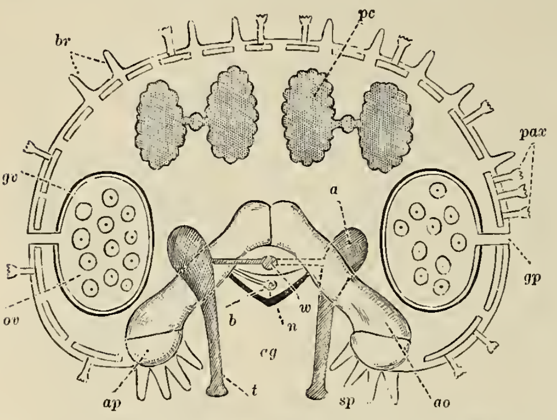


Fig. 9.—DIAGRAMMATIC REPRESENTATION OF A CROSS-SECTION OF AN ARM OF THE COMMON CROSS-FISH (*Asterias rubens*).

On the left side the section is supposed to pass between two of the ambulacral ossicles, but on the right side through one of them (*ao*); *ag*, ambulacral groove; *n*, radial nerve; *b*, radial blood-vessel; *w*, radial water-vessel; *a*, ampullæ; *t*, tentacles; *ap*, adambulacral or lateral plates; *sp*, spines; *pax*, paxillæ, springing from irregular limestone plates; *ov*, ovary; *gp*, genital pore: *gv*, genital blood-vessel; *br*, gills; *pc*, pyloric cæca.

The mouth leads by a short gullet into a wide stomach, the lower part of which is produced in the direction of the rays into five large sacs with folded walls. Above the origins of these sacs the stomach suddenly narrows, and then enlarges into a pentagonal cavity, from the angles of which five forked tubes extend into the rays. Each fork is the stem of a long tree-like mass, which is formed of dense branches of from four to six pear-shaped follicles, all connected with the central stem. These pyloric cæca, as they are called (Fig. 9, *pc*), are supposed to represent the liver of the higher animals. The pentagonal cavity into which they open leads into a short tubular intestine, that usually terminates in a minute anal pore, situated near the centre of the aboral face of the body. Breathing is carried on partly by the tentacles of the water-vascular system (Fig. 9, *t*), and partly by thin-walled tubular processes of the external skin (Fig. 9, *br*), which are ciliated internally, and are in direct communication with the body-cavity; so that a free interchange of gases can take place between the water which they contain and that which bathes their external surface.

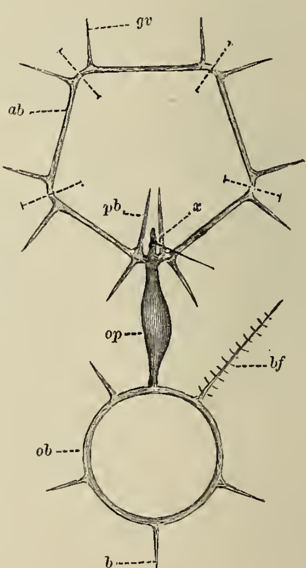


Fig. 10.—DIAGRAM OF THE BLOOD-VASCULAR SYSTEM OF A STARFISH. (*After H. Ludwig.*)

cp, central plexus: *x*, its dorsal extremity: *ab*, aboral blood-vascular ring; *gv*, genital vessels; *pb*, gastric vessels; *ob*, oral blood-vascular ring; *b*, radial blood-vessel; *bf*, its tentacular branches.

The paired genital glands are situated interradially at the junction of the body with the arms, into which they extend for a greater or less distance (Fig. 9, *ov*). Each gland is divided into a number of berry-like clusters, which communicate with the exterior by one or more genital pores. These are either situated in the angles between the arms, or, in the case of the more elongated glands, upon the arms themselves (Fig. 9, *gp*).

The internal skeleton of each arm consists of two longitudinal series of plate-like joints, the "ambulacral ossicles" (Fig. 9, *a o*), which lean against each other in the middle line above, so as to form the sides and roof of the ambulacral groove (*ag*). Between each ossicle and those in front and behind it are small pores, produced by the fitting together of notches upon the front and back faces of the successive joints. The branches from the radial water-vessels (*w*) to the tube-feet (*t*) pass outwards through these pores. The lower ends of the ossicles abut against a series of short and thick "adambulacral plates" (Fig. 9, *ap*), which form the edges of the groove, and usually bear spines (*sp*); while the sides of the arms are protected by a variable number of lateral or marginal plates, also bearing spines (Fig. 1). In some cases also there is an external skeleton of well-defined plates on the upper surface of the arms, but there is generally only a mere network, more or less regularly arranged, and bearing clustered spinelets, or paxillæ (Fig. 9, *pax*).

Attached to some of the larger spines, and in the intervals between them, are numerous little

flexible stalks, each terminating in a pair of pincers. These are opened and shut by special muscular fibres, and are in a state of continual movement, twisting about, and snapping at minute things which come in their way. They are known as "pedicellariæ,"* but their precise functions are not very clear. It has been suggested that they may perhaps act as scavengers, catching up particles of dirt from the surface of the body, and casting it off into the surrounding water.

The Starfishes are excessively voracious animals, feeding indifferently upon shell-fish, crabs, anemones, worms, and all kinds of carrion. Oysters and other bivalves have but little chance against them. The Starfish enfolds the shell with its arms, and protrudes the lower portion of its stomach through its mouth and between the valves of the shell, until it can seize upon the body of its unfortunate occupant. Little by little the great stomach is pushed farther and farther out of its own body and over that of its prey, until at last, if the oyster be a large one, the pouches are withdrawn from the rays, and the Starfish is substantially turned inside out. This work of destruction is sometimes carried on by a number of Starfishes interlacing their arms together, so as to form a ball, which rolls about in the water with the clams, oysters, or other shell-fish in the middle of it. Starfishes are thus very dangerous enemies to the cultivation of oysters. In some places they are so abundant as entirely to prevent any oysters growing at all. The damage done by them on the coast of the United States, between Cape Cod and Staten Island, is estimated at over 100,000 dollars yearly. They sometimes invade the oyster-beds in enormous hordes, coming quite suddenly at intervals of a few years. Such an invasion came to Providence River, Rhode Island, United States, about the year 1860, and caused a loss to the oyster-growers of 150,000 dollars. At another locality 2,500 individuals were speared on an oyster-bed in two days.

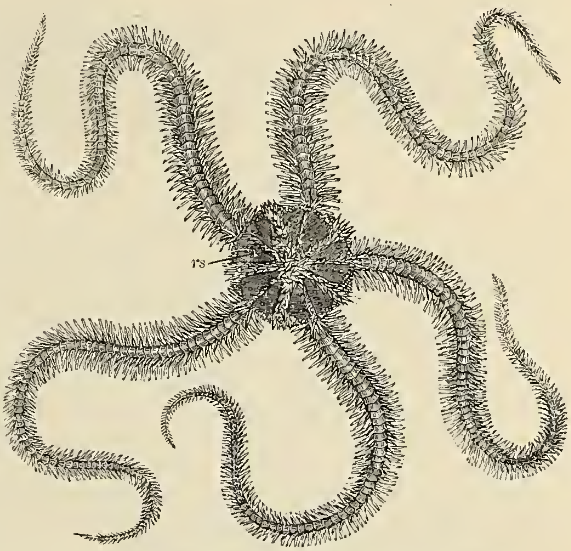


Fig. 11.—THE COMMON BRITTLE-STAR (*Ophiothrix fragilis*).
Natural size. *rs*, radial shields.

When Starfishes were first discovered to be enemies to oyster culture the captured ones were torn across and thrown back into the sea, though not to die; for Starfishes, like all Echinoderms, have a considerable power of reproducing lost parts, a single arm having been known to grow up into a new Starfish. Consequently, instead of diminishing the pest, the above method of procedure would tend to directly increase it, two or three new enemies being made out of every captive. Now, however, the oystermen hand their captures over to the gardeners, by whom Starfishes are much valued as manure. The common Crossfish (*Asterias rubens*) is largely used for this purpose on both sides of the English Channel, and also in the Eastern Counties. This species is also known as Five-fingers, Five-fingered Jack, and the Devil's-fingers or the Devil's-hands, these latter names being used upon some parts of the Irish coast, where a Starfish is looked upon with superstitious dread.

(2) *Ophiuroidea.* The name of this class is derived from the three Greek words: *ophis*, snake, *oura*, tail, and *eidos*, form, and refers to the external form of these creatures (Fig. 11). They have longish serpent-like arms attached to a relatively small and usually rounded body or disc, to which the viscera are confined. The top and sides of the disc generally bear plates or scales of various sizes; and they are often more or less covered with limestone granules, spinelets, or even with groups of spines. The precise mode of arrangement of the plates on the top of the disc varies in different species; but five pairs of plates, known as the "radial shields" (Fig. 11, *rs*), are always present, though not always visible. Each pair corresponds to the base of one of the arms or rays, one plate lying on either side of the ray, not far from the edge of the disc. This is usually, but not always, notched for

* Latin, diminutive of *pediculus*, a louse.

the arm-bases, that dovetail, as it were, into the disc, and are visible on its under side, separated from one another by groups of regularly-arranged plates, which converge towards the central mouth. Each arm-base is separated from the plated interradial areas at its sides by slit-like openings, which are usually single, but occasionally double. These are known as the genital slits, and lead into thin walled pouches at the sides of the rays, to which a two-fold function has been assigned. In a living Ophiurid a double current of entrance and exit is visible around these genital slits, its cause appearing to lie in the alternate expansion and contraction of the disc; and the pouches thus seem to serve as a kind of internal gills, or breathing apparatus. The water which enters them brings in oxygen, which it exchanges for carbonic acid with the water in the body-cavity through the thin wall of the pouch, and then goes out by the return current. The ovaries of the Ophiurids open into these pouches, and the ripe ova may either be carried out through the genital slits by the efferent currents, so as to undergo their larval metamorphoses independently of their parent, or they may remain within the pouches, and undergo a direct and more rapid development, as has been mentioned above.

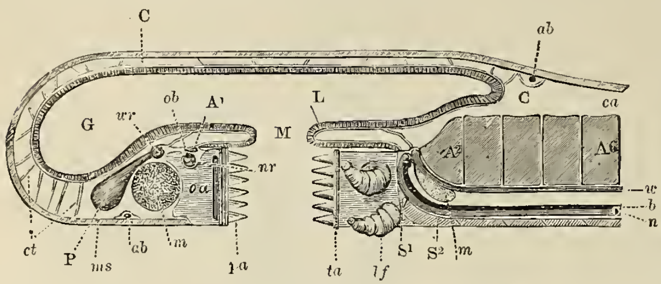


Fig. 12.—DIAGRAM ON A LONGITUDINAL SECTION THROUGH THE DISC AND AN ARM-BASE OF AN OPHIURID. (*After H. Ludwig.*)

M, mouth; L, lip; G, stomach; C, body cavity; *ca*, its extension into the arm; *ct*, connective tissue bands; A1, A2, A6, successive ambulacral ossicles; S1, S2, &c., lower arm-plates; *oa*, oral angle; *pa*, paleæ angulares; *ta*, torus angularis; *m*, muscle; *ms*, mouth-shield; *ab*, aboral blood-vascular ring; *ob*, oral blood-vascular ring; *b*, radial blood-vessel; *w*, radial water-vessel; *wr*, water-vascular ring; P, Polian vesicle; *bf*, buccal tentacles; *nr*, oral nervous ring; *n*, radial nerve.

At the inner angle of each interradial area on the under surface of the disc is a plate known as the "mouth-shield" (Fig. 12, *ms*). Between each of these and the mouth is a complicated arrangement of plates, constituting what is called an oral angle (Fig. 12, *oa*, *ta*, &c). At the apex of this are a number of short flat processes, the *paleæ angulares* (Fig. 12 *pa*), while its sides bear numerous smaller processes, the "mouth-papillæ." These serve as strainers, keeping foreign bodies that are not wanted for food from entering the stomach. The paleæ angulares probably serve much the same purpose, though they are often spoken of as teeth. They have, however, little or no crushing power, as there is usually hardly any room for any play of the oral angles to and from the central axis of the body. The mouth of an Ophiurid is surrounded by twenty tentacles, two on either side of each oral angle, which is pierced for their passage (Fig. 12, *bf*). These buccal tentacles, which are merely the modified tube-feet of the two first arm-joints, are in a state of continual movement. They assist the food in entering, and they also serve to clear away the undigested residue, which is ejected from the mouth, as there is no second opening to the stomach. This organ (Fig. 12, G) is a wide-mouthed bag, attached to the sides and top of the disc by bands of connective tissue (*ct*), and capable of a certain amount of protrusion; but there are no extensions of this simple digestive apparatus into the arms, as there are in the Starfishes.

The plates making up the oral angles are rather thick, as compared with the height of the disc, and the water-vascular ring lies in a groove on their upper surface (Fig. 12, *wr*). It communicates by a short water-tube with pores in one of the interradial mouth-shields, which represents the madreporite of the Starfish. Four Polian vesicles may also be connected with it (Fig. 12, P), one for each of the remaining interradii; but there are sometimes none at all, while on the other hand they may take the form of numerous irregular blind tubes.

The blood-vessels and nerves have the same relation to the water-vascular system as in the Starfish.

The central plexus connecting the oral and the aboral blood-vascular rings is enclosed in a common sheath together with the water-tube, just as in the Starfish. The aboral ring (Fig. 12, *ab*) lies immediately beneath the radial shields at the base of each ray; but it dips down in the interradial spaces alongside the genital slits, and rests on the mouth-shields, one of which is perforated by the water-pores. Consequently the central plexus and the water-tube descend from the oral ring instead of ascending, as they do in the Asterids.

The arms of the Ophiurids are rather appendages to the body (Fig. 11) than actual portions of it, as is the case in the Asterids (Fig. 1). The greater part of each arm is formed by a central bony axis, which is composed of successive joints, and fills up almost the whole of the internal cavity of the arm. Each of the quadrate axial ossicles (Fig. 12, A^6; Fig. 13, *ao*) consists of two lateral halves, which are united in its middle line, and represent the smaller and less-developed ambulacral ossicles in the arm of a Starfish (Fig. 9, *ao*). The successive ossicles are connected by pairs of strong muscular bundles, and articulate by tenon and mortice joints upon their terminal surfaces.

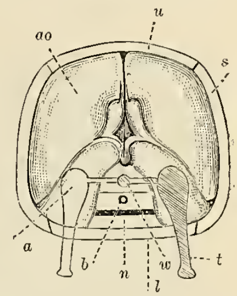


Fig. 13.—DIAGRAM ON A CROSS-SECTION OF AN OPHIURID ARM (*slightly altered from Sladen*).

ao, ambulacral ossicle; *u*, upper arm-plate; *s*, side arm-plate; *l*, lower arm-plate; *n*, radial nerve; *b*, radial blood-vessel; *w*, radial water-vessel; *a*, ampulla; *t*, tentacles.

Corresponding to each ossicle of the internal skeleton are four superficial plates, viz., the "lower arm-plate" (Fig. 12, s^2; Fig. 13, *l*), the upper "arm-plate" (Fig. 13, *u*), and two "side arm-plates" (Fig. 13, *s*). These plates are often more or less covered with spines, as is shown in the specimen figured (Fig. 11). On either side of the under arm-plate, between it and the side arm-plates, are openings by which the tube-feet reach the exterior. Each opening is protected by a little scale or scales, which may be upon the side arm-plate, or upon the lower arm-plate, or upon both.

The tube-feet have less to do with locomotion than their fellows in the Urchins and Starfishes, as they have no terminal suckers, but they are very sensitive to touch. Their chief function is probably respiratory, while locomotion is effected by means of the worm-like arms, which are capable of a very considerable amount of lateral movement, though they cannot be bent to any great extent. The Ophiurids are much more active than the Asterids, and of them the Brittle-stars are more so than the Sand-stars, seldom remaining quiet for a moment, but keeping their arms in a state of continual twisting movement. They also have a singular power of breaking their arms into fragments, which are often flung away to some little distance from the disc, new ones growing out from it again after a longer or shorter interval, for the power of reparation which these animals possess is very considerable.

Most of the *Ophiuroidea* have simple and undivided arms (*Ophiurida*, Fig. 11); but in the members of the order *Astrophytida** the arms fork ten or twelve times, and the numerous branches into which they divide interlace with one another, so as to form a sort of trellis-work all round the disc. These creatures are variously known by the names of Basket-fish, Medusa-head Starfish, and Argus.

The habitat of the Sand-stars may be gathered from their name, while the Brittle-stars are to be found both on a sandy bottom and in the rock-pools on the shore. Many of them are very abundant in the neighbourhood of oyster-beds and scallop-banks, and are largely preyed upon by the cod and other fish, while their own stomachs are full of minute foraminiferal shells.

(3) *Echinoidea.* The members of this class are variously known as Sea-eggs, Sea-hedgehogs, or Sea-urchins. The last name, used as it often is without the prefix, is merely a corruption of "Oursin," the French word for hedgehog. This appellation is not bestowed without reason, the body of any common Echinid being more or less globular and covered with spines. These spines are jointed on to knobs or tubercles, which are borne by the closely-fitting limestone plates of the test or shell (Fig. 14, A, B). The tubercles do not, however, cover the whole surface of the test indiscriminately, but they are chiefly disposed in five broad zones, which extend from one pole to the other. Alternating with these are five narrower zones, which bear smaller and fewer tubercles, and are pierced with small holes arranged in regular rows. Through these holes the Urchin extends its tentacles or tube-feet, which are provided with terminal suckers, like those of the Starfishes, and are largely used in locomotion, especially when the creature is climbing a steep slope. On level surfaces, however, the spines are also brought into play, the animal advancing by a sort of tilting motion.

Scattered among the spines are pedicellariæ, resembling those of the Starfishes, except that they have three prongs instead of two (Fig. 14, C, D). They are said to be used in climbing for laying hold of fronds of seaweed, and so enabling the Urchin to steady itself until it can make use of its sucking feet. They are also employed as scavengers, those round the anal opening laying hold of the ejected

* Greek, *aster*, star; *phuton*, plant; *eidos*, form.

remains of the food, and passing them on to those below. These, in their turn, close upon the particles, and pass them down the sides of the body until they can drop off into the water without becoming entangled among the tentacles and spines.

Each of the narrow poriferous zones in the test of an Urchin is spoken of as "ambulacral," owing to its being pierced for the passage of the tentacles of the ambulacral system; while the five broader zones which alternate with them, and bear larger tubercles, are "interambulacral." Each zone, whether ambulacral or interambulacral, consists of a double series of alternating plates, as is well shown in Fig. 14, A, B. All the zones converge towards the summit of the test, where, in the regular Urchins (*Desmosticha**), the anal opening is situated. It occupies a more or less excentric position within a space which is known as the periproct,† and is wholly or partially filled up by minute limestone plates. The periproct is separated from the apices of the ambulacral and interambulacral zones by two rings of larger plates alternately arranged (Fig. 14, A). Those of the inner ring, which terminate the interambulacral zones, are pierced by the ducts of the genital glands. One of them, that occupying a N.E. position in the figure, is pierced by the water-pores, and thus represents the madreporite which is at the upper extremity of the water-tube of the Starfish (Fig. 1, *m*). The plates of the outer ring are pierced by the unpaired tentacles, which terminate the water-vascular trunks, and represent the "ocular tentacles" at the ends of the Starfish arms.

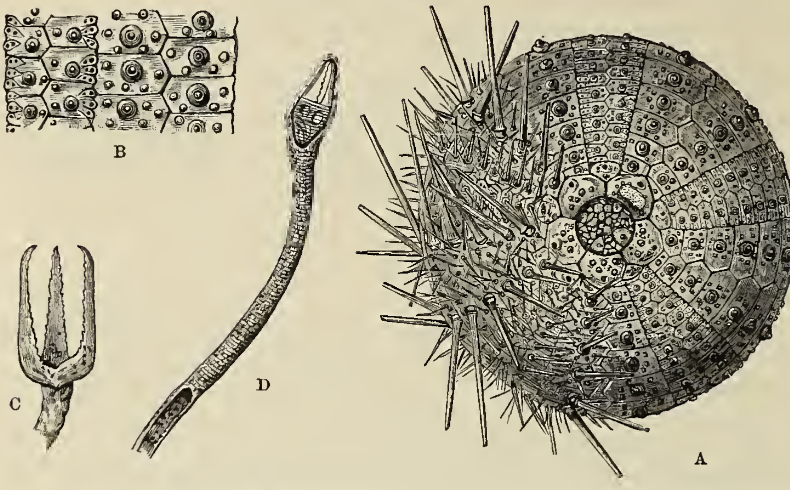


Fig. 14.—A GENERAL VIEW OF THE TEST OF AN URCHIN (*Echinus microstoma*), FROM ABOVE. NATURAL SIZE. (*After Wyville Thomson.*)

A, Most of the spines have been removed. The madreporite is seen on the genital plate lying N.E. of the centre. B, Portions of the ambulacral and interambulacral zones in the test of *Toxopneustes variegatus*. Enlarged. (*After Agassiz*) C, Head of Pedicellaria with the valves open. (*After Erdl.*) D, Pedicellaria with the valves closed. (*After Valentin.*)

In the regular Urchins (*Desmosticha*) the mouth and anus are at opposite poles of the vertical axis of the shell; but either one or both may be more or less excentric. In the *Clypeastrida*‡ (Cake-urchins) the anus is near the margin of the dorsal surface, while in *Spatangus*§ (Heart-urchin or Sea-bun) and its allies the anus is marginal, or even on the under-surface of the test, in which the mouth may also occupy a more or less excentric position.

In the *Desmosticha* and *Clypeastrida* the mouth is provided with a very complicated masticating apparatus, which attains its highest development in the former group. It consists of twenty principal pieces arranged into a five-sided conical mass, which was aptly compared by Aristotle to a lantern (Fig. 15, A, B). In the centre of the whole are five teeth working in bony sockets, or pyramids, that are connected by muscles with one another, with the interior of the test, and with the arched auriculæ already

Fig. 15.—A, INTERNAL VIEW OF THE TEST OF *Echinus microstoma*, SHOWING THE DENTAL PYRAMID OR LANTERN OF ARISTOTLE IN THE CENTRE OF THE RING OF AURICULÆ, NAT. SIZE; B, THE DENTAL PYRAMID. (*After Wyville Thomson.*)

* Greek, *desmos*, a band; *stichos*, a row.
† Greek, *peri*, round about.
‡ Latin, *Clypeus*, a shield; Greek, *aster*, a star; *eidos*, form.
§ Greek, *spatanges*.

mentioned, which are well shown in Fig. 15, A. Two other sets of accessory pieces connect the pyramids together, and serve as attachments for muscles, the number of these organs which are concerned in moving the whole lantern being thirty-five.

The teeth move concentrically around the opening of the gullet (Fig. 16, *œ*), which passes upwards through the lantern, and is continued into an elongated digestive tube (Fig. 16, *i*). This exhibits no differentiation into stomach and intestine, but is coiled spirally around the interior of the test, to which it is attached by a mesentery. It is accompanied by two blood-vessels, the one dorsal and the other ventral, which are connected with one another by an extensive vascular network in its walls. The ventral vessel arises from an oral ring, which is situated, together with the water-vascular ring, on the upper surface of the lantern. It is probably (though we do not as yet know with certainty) connected with an aboral ring, from which the vessels supplying the genital glands are given off, and in which the dorsal intestinal vessel may perhaps arise. The central plexus is in intimate relation with the water-tube which descends from the madreporite to the water-vascular ring. This last usually bears five Polian vesicles, and gives off the radial vessels, which descend the sides of the lantern, and then pass outwards beneath the arches of the auricles (Fig. 16, *p*, *po*). The bases of the lateral tentacular branches which they give off open into large ambulacral vesicles, just as in the Stellerids. These radial water-vessels are accompanied by the radial blood-vessels and nervous trunks. The latter start from an oral ring, which is not above the lantern as the vascular rings are, but is close down upon the buccal membrane lying between the gullet and the tips of the teeth, which project from the lantern. The tentacular branches of the radial nerves pass outwards through the same pores in the ambulacral plates as the tentacles themselves, and also communicate with an extensive nervous network, which penetrates the delicate membranous layer surrounding the test, and furnishes nerves to the pedicellariæ and spines.

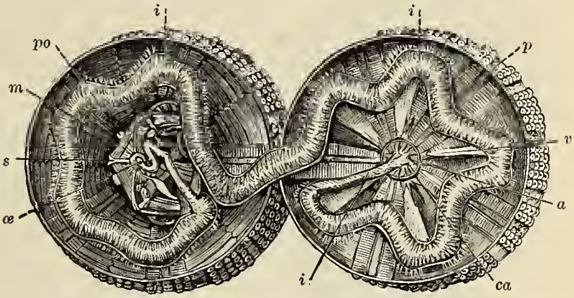


Fig. 16.—VIEW OF THE INTERIOR OF THE BISECTED TEST OF THE PURPLE EGG-URCHIN (*Echinus lividus*).

œ, gullet; *i*, intestine; *a*, anus; *p*, a water-vessel; *po*, oral end of another; *ca*, ocular plate; *s*, one of the pieces of the dental pyramid; *m*, one of the jaw muscles; *v*, ovary. (*After Tiedemann.*)

In most of the regular Urchins there are ten gills in the neighbourhood of the mouth. These are thin-walled ciliated extensions of the closed body-cavity, which protrude between the buccal membrane and the lowest plates of the test, and assist in the work of respiration. In the irregular Urchins this function is exclusively performed by the water-vascular system, and some of the tentacles are specially modified, becoming broad, flat, and somewhat lobed. These are often spoken of as ambulacral gills.

The genital glands of the Urchins are situated in clusters beneath the aboral portion of the test, and communicate with the exterior by the pores in the genital plates.

All the Urchins are gregarious, and many of the Desmosticha inhabiting coasts that are much exposed to the action of the waves protect themselves by hollowing out cavities in the solid rock, even in granite. This is especially the case with the purple Egg-urchins of our coast. They chisel out the rock with their teeth by incessantly turning round and round, commencing when young, and continually enlarging their prison to allow for the growth of their test and spines. The irregular Urchins, on the other hand, mostly prefer quiet sandy places, where they can bury themselves.

(4) *Holothuroidea.* The Holothurians, which are also known as Sea-cucumbers, Trepangs, or Bêches de Mer, are the most worm-like and the least radiate in form of all the Echinoderms. They have more or less elongated bodies (Fig. 17) enclosed in a tough skin, which contains only a comparatively small amount of calcareous matter; and this (except in rare cases) never forms a continuous armour of plates, but occurs only in the shape of scattered grains, which often assume very definite and regular forms. There may, however, be a ring of limestone plates around the gullet, five of which have the same relation to the radial water-vessels as the auricles

within the test of an Urchin, and also serve the same purpose, viz., the attachment of muscles. These organs are disposed in five bands, which correspond in position with the radial nerves proceeding from the oral ring. The mouth is at one end of the body, and the gullet leads into a long and much coiled digestive tube of tolerably uniform width, which terminates in a large pouch or cloaca, at or near the opposite extremity.

Around the mouth is a fringe of branched tentacles (Fig. 17) connected with the water-vascular ring. In a few species this ring communicates directly with the exterior by means of a water-tube opening upon the surface of the body. But in most Holothurians the water-tube hangs down freely into the body-cavity, and terminates in a sieve-like madreporite. One or more Polian vesicles are attached to the water-vascular ring in the intervals between the origins of the radial vessels, with which tube-feet provided with ampullæ are connected. In some forms (*Cucumaria*)* these tube-feet are evenly distributed, and almost equally developed on all the radial vessels (Fig. 17); but in others (*Psolus*) they are confined to three out of the five vessels, that are arranged in a flat sole-like disc, on which the animal creeps. In the *Elasmopoda* the two lateral vessels of this under surface are the only ones in the body, the three remaining vessels being suppressed; while in *Synapta*† and its allies there are no radial vessels at all, the oral ring and the tentacles connected with it being the sole representatives of the water-vascular system.

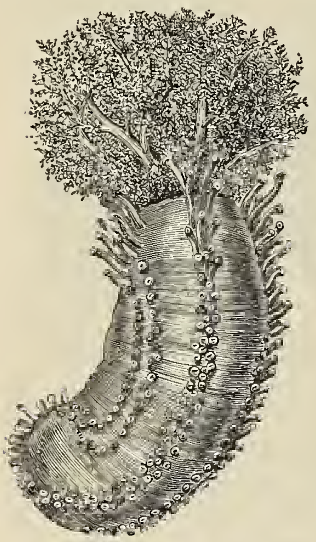


Fig. 17.—A HOLOTHURIAN (*Cucumaria Planci*) WITH ITS BUCCAL TENTACLES EXPANDED. TWICE NATURAL SIZE.

The blood-vascular system consists essentially of dorsal and ventral vessels along the digestive tube, as in the Urchins. These are connected with an oral plexus, from which the radial blood-vessels originate. But no representative of a "central plexus" has yet been made out, except in the *Elasmopoda*, in which the two extremities of the dorsal vessel are united by a large contractile trunk.

Respiration is largely effected by the branched tentacles round the mouth, which are connected with the water-vascular ring. The network of vessels on the walls of the digestive tube seems to take part in the same work, water entering the intestine from the cloacal pouch, which is capable of expansion and contraction. Connected with it in some Holothurians are two branched tubular organs, the "respiratory trees" or lungs, through which water can pass into the body-cavity by fine pores at the ends of the branches. The left lung may be in close relation with the vessels of the dorsal intestinal plexus.

The Holothurians may attain a considerable relative size, some of them being a foot long, and capable of extending to thrice that length. Locomotion is largely effected by the extension and contraction of their bodies, which are continually changing their form by the action of strong muscles, both longitudinal and transverse. Sometimes, indeed, the contractions are so forcible that the creature throws out all its viscera through the cloaca, and lives for a time without them, until it can make good the loss by growing a new set.

The Holothurians of our coasts live among seaweeds or in sand or mud, with the body concealed and the tentacles exposed. They take a great deal of sand into their digestive tube, and the intestines of those which live in the neighbourhood of coral reefs generally contain fragments of coral. When the nutritious matter has been extracted from the coral or sand, the latter is passed out through the cloaca.

The Trepangs of the tropical seas form an important article of food in China. About thirty-five different varieties are enumerated by the Chinese traders, but only about five have any great commercial value. In Fiji they are accounted "royal fish," and used only to be caught by command of the supreme chief. Enough "fish" to fill a three-bushel bag, when dried, may be caught in two nights. The value of such a bagful would be from twenty-five to forty shillings, according to variety and the perfection with which it is cured. The process is effected as follows:—The viscera are

* Latin, *cucumis*, a cucumber. † Greek, *synaptos*, joined together.

removed, and the "slugs" boiled for from ten to twenty minutes. After being well soaked in fresh water, they are arranged on frames in the curing-house. Here they are smoked and dried by means of fires, for which trenches are dug beneath the frames. Four days are required for this curing, after which the Trepang must be kept very dry, for it is remarkably hygrometric, and one damp slug will spoil a whole bag. The final product is an uninviting, dirty-looking substance, which is minced down by the Chinese into a sort of thick soup, a favourite dish among many of the European residents in China and the Philippine Islands.

(5) *Crinoidea.* The Crinoids differ altogether from the other Echinoderms in their mode of life. Instead of crawling about mouth downwards by the aid of tube-feet, a Crinoid remains more or less permanently fixed in one spot, either lying on its back, or growing on a stalk with its mouth upwards. The Stalked Crinoids or Sea-lilies (Fig. 18) are great rarities at the present day, though they were excessively abundant in the seas of some former geological periods, their fossil remains being known as Encrinites or Stone-lilies. Their structure, however, is fundamentally similar to that of the Feather-stars (Fig. 19), which we will now proceed to examine.

As in the Echinoderms generally, there are five rays, which correspond to the five ambulacra in the test of an Urchin (Fig. 14, A). But each of these five rays may fork from one to seven times, so that the number of arms may fall very little short of two hundred. In those of our own seas, however, such as the Rosy Feather-star (Fig. 19), there are rarely more than ten arms. These arms are supported by an internal skeleton of limestone joints placed end to end, and are closely fringed with smaller jointed appendages—the pinnules*—which spring from them like the barbs from the quill of a feather. This feature sufficiently accounts both for the scientific and for the popular names (*Comatula*, Feather-star) of these animals.

Attached to the middle of the back of the Feather-star are a number of little clawed hooks, the cirri (Fig. 20, *ci*), by which the creature can anchor itself to stones and seaweeds. It detaches itself occasionally, and swims about for a while with a peculiarly graceful alternating movement of its arms, eventually settling down in its previous position, with its arms more or less completely extended. On the upper surface of each arm and pinnule is a groove (Figs. 20, 21, *ag*), which corresponds to the ambulacral groove on the under side of a Star-fish arm (Fig. 9, *ag*). It is lined with cilia, which are in a state of continual vibratory movement, so as to produce currents in the water, that carry tiny food particles towards the mouth, where the grooves of all the arms meet (Fig. 19). The mouth may be either almost in the centre of the body or altogether excentric (Fig. 20, M), as in some Urchins. The whole of the coiled digestive tube is lodged within the body (Fig. 20, G), no part of it extending into the arms. It terminates in a tubular projection—the anal tube, the position of which depends upon that of the mouth (Fig. 19; Fig. 20, *at*).

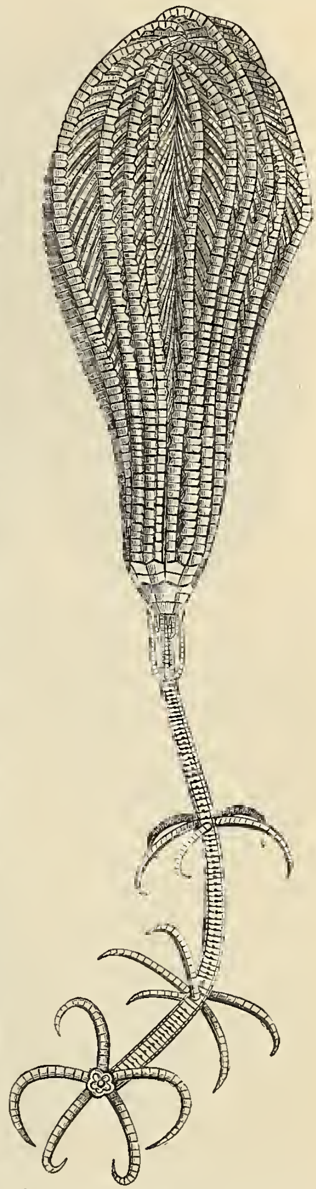


Fig. 18.—A STALKED CRINOID OR SEA-LILY (*Pentacrinus Wyville-Thomsoni*). NATURAL SIZE. (*After Wyville Thomson.*)

The body itself consists of two parts: viz., (1) the cup or calyx formed by the skeleton, and (2) the visceral mass or disc, which is supported within this cup. The bottom of the cup is formed by a more or less saucer-shaped piece, the centrodorsal (Fig. 20, *cd*). Soldered on to this in most Feather-stars are the five first radials (R_1), which correspond to the ocular plates of the Echinoidea. The genital plates of this group are represented by the basal plates of the Crinoid larva (Fig. 8, A, *b*), which in most Feather-stars

* Latin, diminutive of *pinna*, a feather.

gradually disappear from the exterior of the calyx; though in one rare genus and in most Stalked Crinoids they are visible beneath the radials, alternating with them in position, and cutting them off more or less completely from the top stem-joint.

Jointed on to the first radials, and attached to them by muscles, are the five second radials (Fig. 22, R_2), each in its turn bearing a third or axillary radial (R_3). The outer face of this is roof-shaped, and bears the lowest joints (B) of two arms, which may or may not fork again.

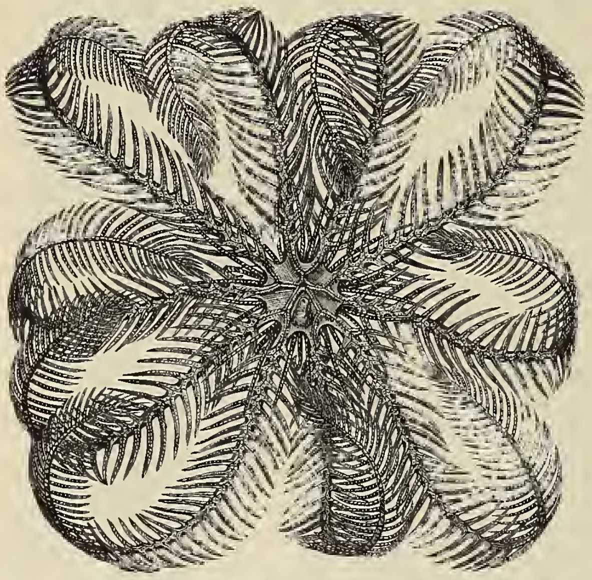


Fig. 19.—THE ROSY FEATHER-STAR (*Comatula rosacea*), VIEWED FROM ABOVE. NATURAL SIZE.

The food grooves of the arms are seen converging towards the nearly central mouth, immediately below which is the projecting anal tube.

Immediately beneath the ciliated ambulacral or food-groove of each arm and pinnule lies a nervous band (Fig. 21, *n*), and deeper still, a blood-vessel (*b*), just as in the groove on the under-side of a Starfish arm (Fig. 9, *n*, *b*). Beneath the blood-vessel is the water-vessel (Fig. 21, *w*), which gives off side branches to the tentacles (T). These are delicate tubular organs, which are situated at the sides of the food-groove, and correspond to the tube-feet of the Starfish (Fig. 9, *t*). Not being required for locomotion, they are essentially breathing organs.

The water-vessels of the arms unite into five trunks which communicate, like those of the Starfish arms, with a ring-shaped vessel (Fig. 20, *wr*), situated in the lip around the mouth. There is, however, no such direct communication between this vessel and the external water as is effected by the stone-canal or water-tube of the Echinozoa. But water is able to enter the body-cavity by innumerable small tubular openings in its walls, the water-pores (Fig. 20, *wp*). These are lined by cilia, all working inwards; and, on the other hand, the water-vascular ring is in free communication with the body-cavity by means of delicate ciliated tubuli—the water-tubes (Fig. 20, *wt*), the open ends of which hang down into it, and thus establish an indirect communication between the body-cavity and the exterior.

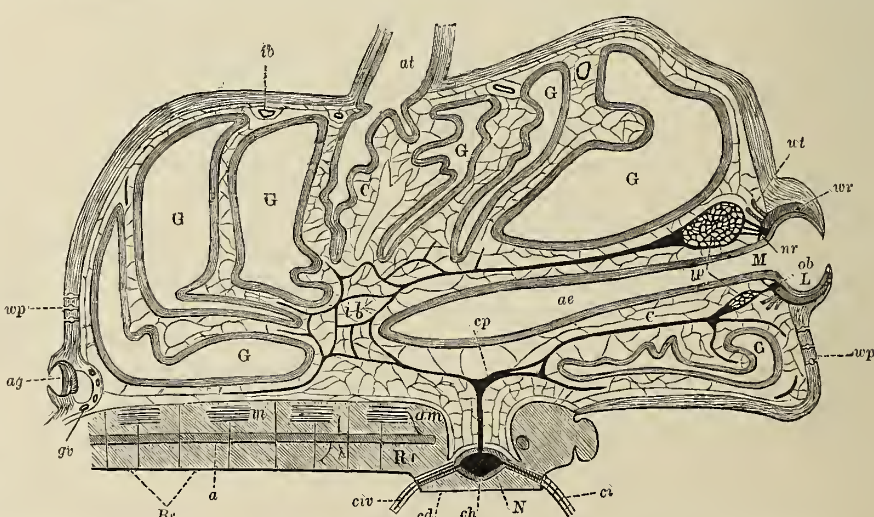


Fig. 20.—LONGITUDINAL SECTION THROUGH THE BODY OF AN IRREGULAR FEATHER-STAR (*Comatula parvicirra*). MAGNIFIED EIGHT TIMES.

a, axial cords of the rays; *ae*, gullet; *ag*, ambulacral groove; *am*, branch of axial cord to muscle; *at*, anal tube; *Br*, arm-joints; *C*, body-cavity, chiefly occupied by connective tissue; *cd*, centro-dorsal; *ch*, chambered organ; *ci*, cirrus; *civ*, cirrus vessel; *cp*, central plexus; *G*, digestive tube; *gv*, genital vessel; *ib*, blood-vascular network over digestive tube; *L*, lip; *lp*, labial plexus; *M*, mouth; *m*, muscle; *N*, fibrillar envelope of the chambered organ; *nr*, oral nervous ring; *ob*, oral blood-vascular ring; *R*1, first radial; *wp*, water-pore; *wr*, water-vascular ring; *wt*, water-tube.

Between the dorsal skeleton of the arms and pinnules (Fig. 21, *pj*) and the water-

vessels, on their upper or ventral side, are three tubular prolongations of the body-cavity. The middle one of these contains the branched generative gland (Fig. 21, *o v*); while a current of water due to ciliary action proceeds outwards along the arms by the upper canal, and returns to the disc by the lower one.

The blood-vascular system of a Crinoid is considerably more complicated than that of the *Echinozoa*, owing to the presence of organs that are altogether unrepresented in that group, and are connected with the development of the stalk which all Crinoids possess for a longer or shorter period of their life. Situated more or less exactly in the vertical axis of the disc is a lobulated organ, the central plexus (Fig. 20, *cp*). This corresponds to the similarly named organ in the *Echinozoa* (Fig. 10, *c p*), and consists of a bundle of blood-vessels. Some of these terminate above in the oral blood-vascular ring (Fig. 20, *ob*), first traversing an extensive network (Fig. 20, *lp*) which is situated in the lip immediately below. Others extend outwards beneath the food-grooves of the disc (Fig. 20, *ag*) into the rays and arms, and surround the genital glands (Fig. 21, *gv*). Others, again, give off side branches, which form a network over the digestive tube (Fig. 20, *ib*). Towards the bottom of the disc the vessels of the central plexus, instead of joining into an aboral ring, group themselves into an inner set surrounded by five outer ones, which correspond in position with the radials. They pass downwards through the central funnel between the inner ends of the first radials, at the bottom of which the five outer vessels expand into five large chambers, which are regularly arranged around the central vascular axis. The structure thus formed, which is known as the "chambered organ" (Fig. 20, *ch*), is lodged within the cavity of the centrodorsal piece (*cd*). It is enclosed in a fibrillar envelope, processes of which extend outwards through all the joints of the rays and arms (Figs. 20, 21, *a*), and also into the cirri (*ci*), or clawed hooks borne upon the centrodorsal. These extensions into the cirri lodge minute blood-vessels (Fig. 20, *ci.v*), which are continuous either with one of the chambers of the chambered organ or with one of the vessels in its central axis. In the Stalked Crinoids the chambered organ is contained within the calyx, and the chambers are continued down the central canal of the stem, as five vessels enclosing a core of smaller ones. When the stem bears whorls of cirri, as in *Pentacrinus* (Fig. 18), the five outer vessels expand slightly in each cirrus-bearing joint, and each gives off one cirrus-vessel, the whole forming a small edition of the chambered organ in the calyx above.

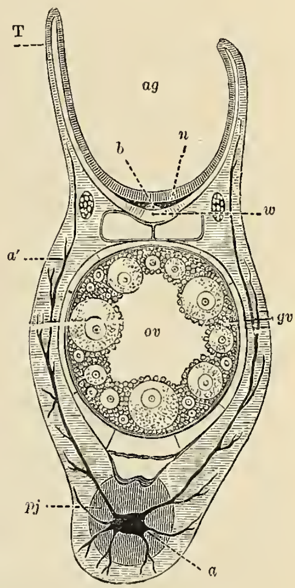


Fig. 21.—CROSS-SECTION OF A PINNULE OF THE ARCTIC FEATHER-STAR (*Comatula Eschrichtii*), MAGNIFIED SEVENTY-FIVE TIMES. (*Slightly altered from H. Ludwig.*)

a, axial cord; *a'*, its branches; *ag*, ambulacral or food groove; *b*, radial blood-vessel; *gv*, genital vessel; *n*, radial nerve; *ov*, ovary; *pj*, pinnule joint; *w*, water-vessel; T, tentacles.

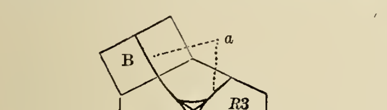


Fig. 22.—DIAGRAM SHOWING THE COURSE OF THE AXIAL CORDS PROCEEDING FROM THE CHAMBERED ORGAN WITHIN THE CALYX OF A FEATHER-STAR. (*After H. Ludwig.*)

a, axial cord; B, first arm-joint; *R1*, *R2*, *R3*, first, second, and third radials.

The course of the extensions into the rays and arms of the fibrillar envelope of the chambered organ, which are known as the axial cords, is seen in Fig. 22. It is very difficult to determine whether they enclose blood-vessels, as the axial cords of the cirri do, but they are of extreme importance in another way. For all the movements of the arms and pinnules depend upon the integrity of their axial cords, and upon the connection of these cords with the central fibrillar envelope of the chambered organ. Some of the extensive branches (Fig. 21, *a'*) which are given off from the axial cords within every joint of the skeleton are distributed to the muscles connecting the successive joints (Fig. 20, *am*).

The nervous apparatus beneath the food-grooves (Fig. 21, *n*) is not connected with the muscles, and has no influence whatever upon the movements of the skeleton, which will continue to swim

about after the visceral mass has fallen out of the calyx, carrying with it the oral nerve-ring (Fig. 20, *nr*). We are led to conclude, therefore, that besides the additional elements in their blood-vascular system, the Crinoids also possess a complicated system of motor-nerves, which is altogether unrepresented in the *Echinozoa*.

The food of the Crinoids is mostly microscopic in character, such as Foraminifera, Infusoria, Entomostraca, and the larvæ of the higher Crustacea. They are very gregarious, as are most of the Echinoderms, the Stalked Crinoids living in great forests on certain parts of the sea-bottom, just as they did in previous geological periods.

During a recent exploration of the Caribbean Sea by the United States Coast Survey, no less than one hundred and twenty-four specimens of Pentacrini were obtained at a single haul of the dredge and its appendages. These must have swept over actual forests of the Sea-lilies, crowded together just as they must have lived in the old Liassic seas. Both in this country (as at Lyme Regis) and abroad large slabs of shaly limestone are found containing collections of fossil Pentacrinites, some of them very perfect and remarkable for the great length of their stems. The total length of the stem of one specimen found in Germany, as measured by its broken pieces, was found to be seventy feet, while others with stems fifty feet long are not uncommon. They must have presented a curious sight in their native seas, each with its long stem on which was the crown of arms, not more than two feet across when fully expanded.

The Crinoids of the Palæozoic period differ very considerably from those preserved in the Secondary and Tertiary rocks. In many of them the mouth was not on the external surface of the body, for it was covered in by a dome of rigid heavy plates. But there were food-grooves on the arms, just as in the recent Sea-lilies and Feather-stars, and at the circumference of the dome were a number of openings, one for each groove, through which the food-particles passed on their way towards the mouth.

The earliest representative of the more modern type of Crinoid in which the mouth is open to the exterior is the "Lily Encrinite," from the Trias of Germany, a very elegant and well-known species. In an old German book about the natural history of Altenburg, dated 1774, it is recorded that the Emperor of Germany once offered a hundred thalers for a good specimen of this Stone-lily attached to its stem, and free from the matrix in which it had been embedded.

Little need be said about the *Cystoidea* and the *Blastoidea*, two groups which are of the highest zoological interest, owing to their furnishing numerous connecting links between the Crinoids and the Echinozoa. They have been extinct since the close of the Palæozoic epoch. They were stalked Echinoderms, like the Crinoids, with food-grooves converging towards a central or excentric mouth, and were provided with respiratory organs, much resembling the interradial pouches of the Ophiurids in their general structure, while it is very doubtful whether their water-vascular system was provided with tentacles. As in the Crinoids, the body-walls were supported by limestone plates, which were arranged very regularly in the Blastoids, but somewhat less so in the Cystids.

Further information upon the subject of the Echinoderms will be found in the works of Agassiz, W. B. Carpenter, Duncan, E. Forbes, H. Ludwig, Lütken, Lyman, Metschnikoff, J. Müller, Sars, Selenka, Semper, Sladen, Wyville Thomson, and others.

P. HERBERT CARPENTER.

THE GROUP ZOOPHYTA.

CHAPTER I.

THE HYDROZOA, OR HYDROMEDUSÆ.

The Group *ZOOPHYTA*—Class HYDROZOA, OR HYDROMEDUSÆ — Characters — Colonies — Reproduction—Order CTENOPHORA—Characters—Venus' Girdle—Order DISCOPHORA, MEDUSÆ, or JELLY-FISHES—Appearance—The Disc—Method of Reproduction—The *Lucernariæ*—Order SIPHONOPHORA—Characters—The "Portuguese Man-of-War"—The Calycophoræ—The Physophoræ —*Velella*—Order HYDROIDA—Genus Hydra—Characters—Gemmation—Power of Reparation—Sub-order TUBULARIA — *Perigonimus* — Characters—Other Tubularians — Sub-order CAMPANULARIA — Sertulariidæ—Plumulariidæ — Sub-order TRACHOMEDUSÆ — Order HYDROCORALLINA — Milleporidæ — Description—Characters—Stylasters—Other Hydrocorallinæ—Classification of the Hydrozoa.

THE Jelly-fish, the Sertularian Polypes, the Hydra, the Sea Anemones, the Alcyonarians, and the Stony Corals are well-known forms of animal life, and their distinctness from the Echinodermata and the other groups already noticed is evident. They constitute the group Zoophyta, and have more or less of a radiate structure, with tentacles; and there is a digestive cavity within their body, with wide or canal-shaped offshoots from it. The hollow space within the body thus occupied has given them another name—Cœlenterata;* but before this term was applied, the plant-like appearance of many of the group had entitled them to the term Zoophyta.† They are distinct from the group Spongida (Sponges), although some synthetic-minded morphologists classify all together as Cœlenterates. Formerly the name of Polypes, or Polypifera, was given, on account of the tentaculate body. There are two classes of the Zoophyta—the Hydrozoa and the Anthozoa.

THE CLASS HYDROZOA, OR HYDROMEDUSÆ.

A vast number of marine and a few fresh-water animals, popularly called Polypes and Jelly-fish, belong to this class. All are very delicately and beautifully constructed, and they present great varieties of shape and methods of life. The fresh-water Hydra, the pretty feathery Polype-stems on sea-shells and rocks, the Sertularians and Tubularians, the Jelly-fish, the Portuguese Man-of-war, the Beroës, the Stony Millepores of reefs, and the coloured Stylasters of the deep sea, all have certain structures in common, in spite of their diverse shapes and habits.

The essential parts of these animals are a mouth, leading directly to a cavity which is digestive in its function, and relates to the circulation of a nutritive fluid, an outer delicate skin, or ecto-derm, encasing the body, and an inner, lining the internal cavity and mouth, and the reproductive organs which are outside the stomachal cavity, and are usually in specially modified parts of the body. These last may be simple sac-like projections of the ecto-derm, or they may be complicated, and have an inner, and also a meso-derm (middle-skin), covered by the ecto-derm, and may resemble ball-shaped Jelly-fish stuck on by their upper part.

The Hydrozoa have tentacles, some very slender and others comparatively stout, and certain stinging cells called nematocysts. The organs of special sense are in a very rudimentary condition, but the tissues as a rule are highly sensitive to irritation, and are very contractile. Some of the class are free-swimmers, and others are fixed during all or part of their life cycle. Most are soft and easily destroyed, but some have very solid sub-structures.

The stationary forms are in colonies of individuals, connected by root-like supports, and in some of the free-swimming kinds there is a colony beneath a float—as in the Portuguese Man-of-war—but the Jelly-fish are solitary. The colonies may be of simple or of branching individuals, some of which are for the purposes of the nutrition and others for the reproduction of the species. In their construction there is an outer and inner derm, and a central cavity reaching from the root-like supports to the mouth. The opening from the outside into the mouth is without a gullet, and the stomach, or somatic cavity, is digestive as well as referable to the circulation, and it may be simple or may be continuous with canals which radiate from it. The reproductive process is very varied. In some free-swimming Jelly-fish the kind is reproduced by the budding of small ones from the region of the mouth, or eggs may be developed and set free, which become like the parents. But these methods

* Greek, *koilos*, hollow; *enteron*, bowel.

† Greek, *zoon*, animal; *phyton*, plant.

are rather exceptional, for the greater part of the free-swimming Medusæ, or Jelly-fish, are the highest developments of individuals which began life in a different shape, and had different habits. The fixed and polype-looking kinds, which have a branched stem, and on it one kind of zooid for nutrition and another for reproduction, develop in certain receptacles of this last, either as larvæ, which escape as ciliated elongate or globular bodies that settle down and become like their parent, or else as plano-blasts—wandering buds—Jelly-fish or Medusæ—which, when they escape, grow and develop sexual elements, and their eggs hatch into the shape of the young individuals of the fixed colony. The generation is then said to be alternate. It is probable, however, that the rudiments of the contents of the generative sacs are developed within the central canal of the body, and pass thence into special organs, and grow into shape. Budding also occurs, and similar forms are reproduced by it. Usually there is great transparency of the tissues, and cilia exist on some kinds, and all have sting- or nettle-cells, or nematocysts in their derm. These are cells with a spiny thread coiled up in them, which escapes on pressure or irritation. The touch of the fine thread, with or without the contents of the cell-sac, produces a paralysing influence on minute crustacea and animalcules, which form the bulk of their food.

The contrast in the dimensions of the Hydrozoa is remarkable; some of the Jelly-fish are several feet in diameter, and others are like little balls, and the branching or fixed kinds may be microscopic or some inches in length; the first are muscular in some parts, and the last are more or less chitinous in their investment. Special senses are represented in the free forms by eye-spots and minute particles of mineral matter or lithocysts, and in most the tentacles which surround the region of the mouth or the margin of the disc of the Medusæ are retractile, and are weapons of offence or of capture. The nervous system is very rudimentary, being more or less in connection with the muscular fibres, in some being made up of nervo-muscular tissues, contractile and sensitive, in the meso-derm, or middle-skin. Haeckel has described a circular band of nerve, on the inner side of the circular canal of the ball-shaped Medusæ, and states that it gives off shoots to the lithocysts, radial canals, cavity, and mouth. But the evidence is not very satisfactory. There is no circulatory system, properly speaking, and no special blood; and the juices of the body are aërated through the delicate tissues. All are aquatic. The Hydrozoa are divided into five orders—the Ctenophora, Discophora, Siphonophora, Hydroida, and Hydrocorallina.

ORDER CTENOPHORA.

These are free-swimming Hydrozoa, usually globular or cylindrical in shape, and rarely ribbon-shaped, and they are more or less lobed. They have rows of flappers placed like lines of longitude on their body, and sometimes two tactile filaments, which can be retracted. The stomach is more or less tubular, and is associated with a series of canals. Never budding, they do not produce colonies or compound organisms, and they are characterised by the great development of the middle tissue, or meso-derm. A nervous ganglion, at the side remote from the mouth, with eight radiating cords to the paddles, appears to have been made out satisfactorily.

BEROË PILEUS.

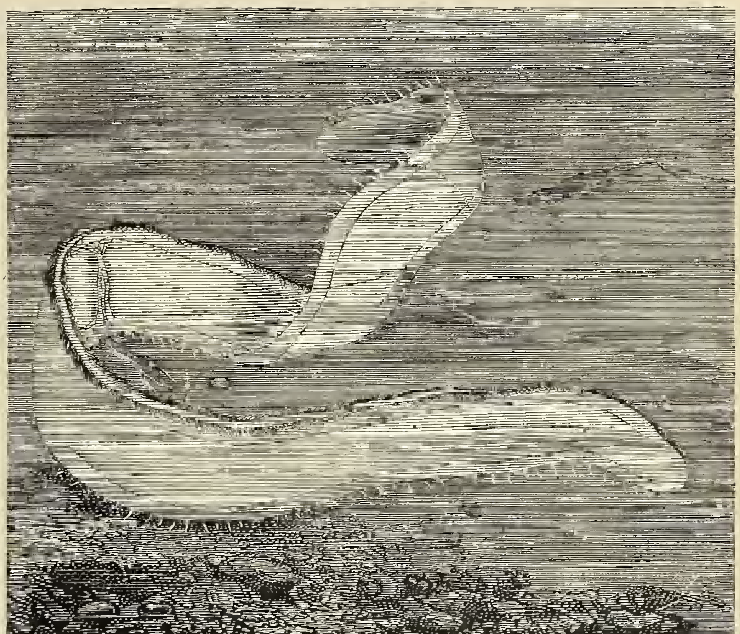
The Ctenophoræ,* not having a disc, and not resembling the Medusæ, or Jelly-fish, in their shape, have a totally different method of moving in the water. Whilst the great Jelly-fish contract and expand their bodies in regular succession, moving in a very stately manner, the Ctenophoræ dart here and there, rapidly ascend, descend, and move slowly at will; so that at night, when the great Medusæ are phosphorescent, and look like pale, slowly-moving spheres under water, the little Ctenophoræ flash here and there with a bright light, and are soon out of sight. They move by the rapid flapping of countless little paddle-like processes arranged in vertical rows along the surface of the body, like the teeth of a comb. The rows may all be in full vigour of movement, or one only may act; and, indeed, separate paddles appear to move independently and at will. The little creatures thus rise and move obliquely, or fall and progress, according to the quantity and the position of the skin machinery which may be used. They can stop and float in mid-water, and again dart off; and A. Agassiz

* Comb-bearers.

noticed that sometimes one-half of their flappers were acting, whilst those of the other side of the body were at rest, thus producing rotary motion.

The combs, which are very small, are placed on horizontal bands of muscular tissue, and when they move by day they are iridescent and very beautiful.

One of the most beautiful of the Ctenophoræ belonging to the globular sub-order is the type of the family Cydippidæ, and is a species of Pleurobrachia.* It is a small transparent sphere, occasionally becoming bulged out, and there is a slit-like mouth on the top, and a dark eye-spot is at the other pole. Eight rows of fringes run, like lines of longitude, from pole to pole, dividing the surface, like the ribs on a melon. Hanging from either side of the body, from just above the eye-speck, are two very long tentacles, like soft fringes of feathers on a spring. They are in rapid movement when necessary, coiling, undulating, and moving the little body in most graceful curves, or they may stream out listlessly, and float behind, a foot or eighteen inches in length. In an instant they may contract, and fold into a knot not larger than a pin's head. The prevailing tint of the little sphere is given by the motions of these wonderful fringes, and it may be yellowish, pink, green, red, and purple. These arise from small sacs, into which they may be withdrawn. The mouth is brought constantly within reach of its minute prey—small immature marine animals and plants—by the motion of the fringes, and the food passes down a wide digestive cavity between two tubes. These unite at the lower part of the body in a single funnel-shaped cavity, which is a reservoir for the circulating fluid poured through an opening in the digestive cavity into it. The food and much water pass into this canal and are sent ramifying through a series of tubes about the body. These chymiferous tubes start horizontally and at right angles to the digestive cavity, from the point of junction of the vertical tubes and the canal. When they reach the periphery, each one joins a longitudinal tube which is just within one of the rows of flappers, and more or less connected with it. The Atlantic, and the northern parts especially, are favourite localities of this genus, but others of the family are found in the Mediterranean and the Pacific Ocean.



VENUS' GIRDLE (*Cestum Veneris*).

The pretty Beroë and the genus Rangia belong to the sub-order Eurystoma, and their oval bodies are contractile, and without lobes and tentacular filaments of much length. The mouth and stomach are large.

Some of the Ctenophoræ, such as the Bolinæ, are lobed in the region of the mouth, which is downwards, and the body departs from the globular shape and does not have long tentacles. They move with a sluggish, slow, and undulating movement, and have the eight rows of small paddles, but they differ in length according to their position on the body. The motion is assisted by appendages, called auricles of the lobes; and the whole animal, according to Agassiz, resembles a white flower with the crown expanded, and especially when it reverses itself and floats mouth upwards. The genus is found in the Northern Seas.

The family Cestidæ belongs to the ribbon-shaped order; and *Cestum Veneris* (Venus' Girdle) of the

* *Pleurobrachia rhododactyla.*

Mediterranean, is a long, slender, narrow, strongly-compressed, very agile creature, rather enlarged in front and behind. There are two tactile filaments, each one with an offshoot, and they are fixed to the buccal or mouth region, which is carried downwards. It is covered with moving cilia, and four ranges of motile organs, and four vessels are noticed on the upper part of the body. Four other vessels are in the lower part, and they are in communication. The graceful undulating movements of this Cestum have always excited the admiration of those naturalists who have had the good fortune to see them.

Some of the Ctenophoræ are very abundant, and hundreds of the group, characterised by having bell-shaped body and belonging to the Eurystomæ, are caught in the Northern Seas when fishing-nets are brought up. The common Beroë of our coasts is one of them, and so is the Rosy Idya of the American Seas.

All the Ctenophoræ are produced from eggs, and the young swim in the egg long before they are set free; they have the flappers of great size in relation to the rest of the body. An examination of the development of the young of the different great groups proves that certain structures, which last on in the less complicated forms, are transient in the higher ones.

ORDER DISCOPHORA.—THE MEDUSÆ, OR JELLY-FISH.

Everybody is familiar with the appearance of the large Jelly-fish which move so gracefully by expanding and contracting their umbrella-shaped discs, and on the surface of which four more or less circular coloured patches are to be seen. Hundreds may be seen on our coasts, swimming with the tide, and rising and sinking in the clear sea in the summer-time. They are semi-transparent and almost colourless when seen by daylight, and some of them are luminous at night. When one is caught by the hand, unless care be taken, the fingers enter its tender substance, and it falls motionless into the water. And when one is found stranded and dead on the sand, the edge of the disc is seen to be lobed and furnished with a fringe of thread-like tentacles; the circular spots on the top are also visible, and so are numerous markings, like lines, eight often being principal, passing from the top of the disc to its circumference, and uniting in a canal which passes all round the edge, just within the substance of the Jelly-fish.

On turning this Discophora or Medusa on its back, and looking at the under surface of the disc, a central opening is to be found, into which the finger can pass. This is the mouth, and the passage leads through the substance of the disc to a cavity, the stomach, which is surrounded by the four coloured circular spots.

The substance of the disc has an outer very delicate skin covered with cilia, and on the under surface of the disc muscular fibres stretch from the margin to the edge of the mouth. In some very large kinds* the substance itself is rather tough; and yet Agassiz states that one which weighed 34 lbs. being left to dry in the sun for some days lost $\frac{99}{100}$ths of its original weight. Such an one would be seven feet in diameter without its tentacles; but from one to five feet are the common sizes. Hence these great discs principally consist of water, and it is held in the meshes of a connective tissue, which contains cells possessing amœboid movements. The skin which lines the mouth and the stomach also enters the four circular cavities, and also the canals which radiate from the stomach in the disc substance, and reach the circular canal.

At the bottom of each of the notches on the edge of the disc which separate it into lobes is a small oval body containing calcareous matter on a minute stalk, the cavity of which is continuous with one of the radiating canals just noticed. Pigment may also exist about the little body, which has been called a lithocyst, and has been deemed an organ of special sense for hearing or seeing, or both. A membranous covering usually protects the so-called eyes.

The entrance to the mouth is in the midst of a part of the body which is denser than the rest, and, indeed, the disc may be considered to be an appendage. It is made up of four parts, which may be divided so as to present eight radiating arms, in the midst of which is the passage to the stomach. This part, which hangs down, when the disc is in motion, is called the hydranth. The circular spots are reproductive organs, and the eggs escape from them into the stomach, and pass forth through the mouth. In some kinds the stomach has pouches, and in all, the radial canals whether

* *Cyanea arctica.*

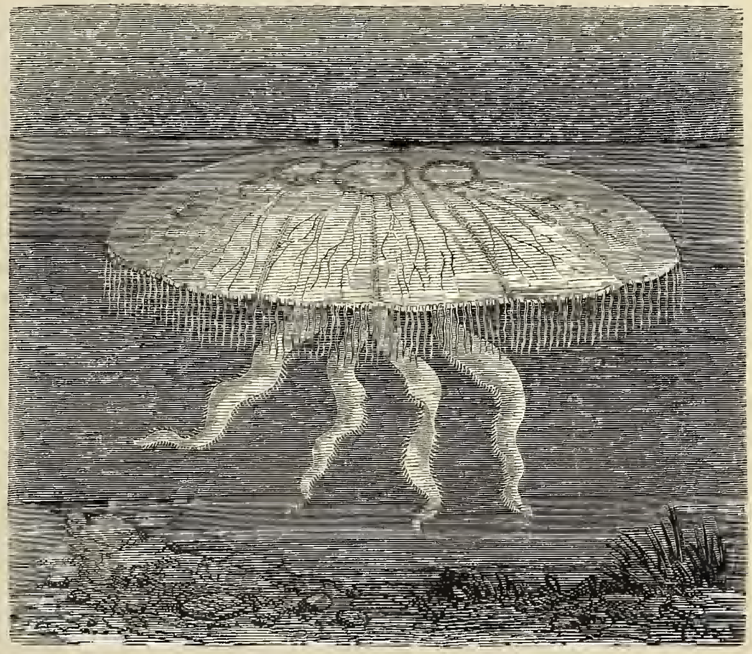
JELLY-FISHES.

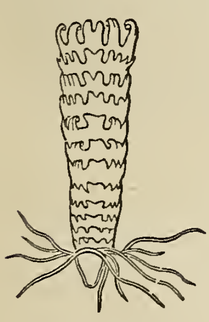
simple or ramified, carry the digested food to the circular canal. No special organs of circulation exist, and respiration is effected by the membranes or skin of the disc.

The fringe of tentacles around the disc may be very short and sparely developed, or these appendages may be many feet in length and very numerous. They are supplied with nematocysts, which are the stinging organs, and which are sufficiently annoying to some thin-skinned bathers.

The nervous system may exist in relation to the eye-spots, and in a very rudimentary condition elsewhere. Small swimming Invertebrata are the food of the Medusa.

The methods of reproduction and development are very remarkable, and the dimensions of the full-grown disc are greatly in excess of those of the first stage of life. One great group of the Discophoræ, including the common Jelly-fish of our seas, lay eggs in the autumn when they are swimming in the neighbourhood of the coasts and estuaries. The parent dies, and the young escape from the eggs as little spherical bodies, covered with cilia. Each one attaches itself by its base to a rock or seaweed, and tentacles are formed at the other end, the body gradually becoming elongate. With growth some contractions occur around the young form, the first being just below the circle of tentacles. Tentacles soon appear on the edges of the contraction nearest the base, and the edges of the other contractions simply become lobed. After a while these contractions become deep, and the animal resembles a set of plates placed one over the other, the top and bottom ones having circlets of tentacles. At a certain period, when the whole is less than an inch in height, the entire structure breaks up; the top falls off and dies, and the bottom part remains fixed, whilst the rest separates into as many discs as there were contractions and each swims off to become a gigantic Discophora.* This process is a good example of the alternation of generation, and the young and tentacled form is the nurse or intermediate stage. It has been called "Hydra-tuba," and in the next stage it is called Strobila.

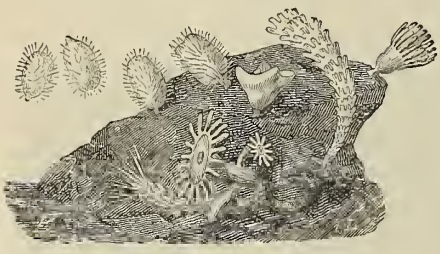

AURELIA AURITA.


STROBILA OF AURELIA FLAVIDULA. (After L. Agassiz.)

The Discophoræ include the great free-swimming oceanic Medusæ, but it is not clearly proved that all do pass through the peculiar stages of development. Some may have a very different early life, and may belong to other groups of the Hydrozoa. Two sub-orders are distinguished. The Pelagida, containing such genera as Cyanea, Aurelia, and Pelagia, have a large central mouth surrounded with four arms, often subdivided, and fixed on to a buccal peduncle. The fringes of tentacles on the lobed margin of the disc may be long or short. The genital organs are four. The Rhizostoma have a great development of the structures surrounding the mouth, which gives the name from their root-like appearance. The mouth, with growth, closes at its lips, and passages into the digestive tract are formed down the rootlets, at the ends of which are small openings, like little suckers. There are no marginal filaments.

* Example, *Aurelia flavidula*

One of the prettiest free-swimming Medusoids is more or less bell-shaped, but it has a stalk-like top, by which it can attach itself to weed or rock, and the margin of the bell is separated into eight knobs, or lobes, covered with tentacles. The membrane of the bell is festooned between the lobes, and the whole animal is very transparent. These Lucernariæ are very contractile, and can change their shape, and their movements are most varied. They swim by contractions and expansions of the disc, like ordinary Jelly-fish; but when they settle down, the lower part of the disc curves up and the body is fixed on its peduncle. L. Agassiz, in his charming book on the marine animals of Massachusetts Bay, writes:—"It frequently secures itself in the upright position, spreading itself in the form of a perfectly symmetrical cup or vase, the margin of which is indented by a succession of inverted scallops, the point of junction between two scallops being crowned by a tuft of tentacles. But watch it for a while, and the sides of the vase turn backward, spreading completely open, till they present the whole inner surface, with the edges even curved a little downward, drooping slightly, and the proboscis rising in the centre. In such an attitude one may trace, with care, the shape of the mouth, the lobes surrounding it, as well as the tubes and cavities radiating from it towards the margin. A touch is, however, sufficient to make it close upon itself, shrinking together, or even drawing its tentacles in and contracting all its parts, till it looks like a little ball hanging on the stem. These are but few of its manifold changes, for it may be seen in every phase of contraction and expansion."


REPRODUCTION OF DISCOPHORA.

The bell is not a hollow hemisphere, but is a mass of gelatinous hardness, and the peduncle is an extension of the bell, and it has a minute disc at the end, for attachment. The mouth is in the midst of the bell, which has an inverted look, is square, and is on a projecting proboscis. The body-cavity is four-chambered, and each communicates with the mouth. Triangular-looking structures pass outwards to the tentacular knobs, and are the ovaries, consisting of a number of little bags, each crowded with eggs. These drop into the stomach, and are passed out of the mouth. The tentacles are club-shaped, and they have an orifice which leads through a canal to the chambers of the digestive cavity, two of the clusters being connected with each chamber. "Their chief office," writes L. Agassiz, "is to catch food and convey it to the mouth; but the Lucernaria frequently uses them in locomotion, fixing itself by them, and loosing the end of its peduncle." Between the clusters are slight projections, which are short and compact, and they are used as claspers to a certain extent. They contain a slight pigment spot, which may be an eye. The colour of the American form (*Lucernaria auricula*) is greenish, with a faint tinge of red, and it assumes a beautiful aquamarine tint. The British species thrive in aquaria, and are very beautiful objects.


LUCERNARIÆ ON PIECE OF SEAWEED (*Lucernaria octo-radiata*).

ORDER SIPHONOPHORA.*

These are free-swimming Hydrozoa, but each one consists of a colony or assemblage of individuals united in a common stock, termed a hydrosoma,† and placed under a more or less tough part, which acts as a float. This last may be large and crested, or it may be small, and united to others which fulfil the same office. An air-sac, from which air can be expelled, enters into the composition of the float.

Nutritive and generative individuals, or zooids, exist in the colony, and long pendant tentacles add to the beauty of the forms. In some an oil bubble, surrounded by tissue, acts as a float. They reproduce by developing buds, which give forth planoblasts (wandering buds) or medusæ. These develop eggs, which grow into the shape of the float and colony.

The "Portuguese Man-of-War"‡ may be seen in the tropics sailing on the surface of the sea, its

* Tube, or siphon-bearers. † See Note on p. 286. ‡ *Physalia utriculus.*

coloured float, with a crest to it, being partly above water, and a multitude of tentacles, some long and others short, trail behind in the waves.

The float is sac-like, long, pointed at one end and rounded at the other, and there is a small opening at either end surrounded by muscular fibres. When the float is held in the hand, it feels light, and a little pressure forces air out of it. The sac contains an enlargement of the digestive cavity, and also a long air-sac, divided by muscular partitions, which do not, however, communicate with the digestive cavity, but open externally. Beneath the float are numerous long tentacles without lateral branches, and with kidney-shaped enlargements here and there, armed with nematocysts. Besides these, there are a host of shorter structures, forming, really, a hydroid colony. There are tentaculate individuals, or zooids, called trophosomes, in groups which deal with the nutrition, and bunches of other individuals, or gonophores, with medusa-like buds, and which are reproductive. These escape, and the Physalia is their product.

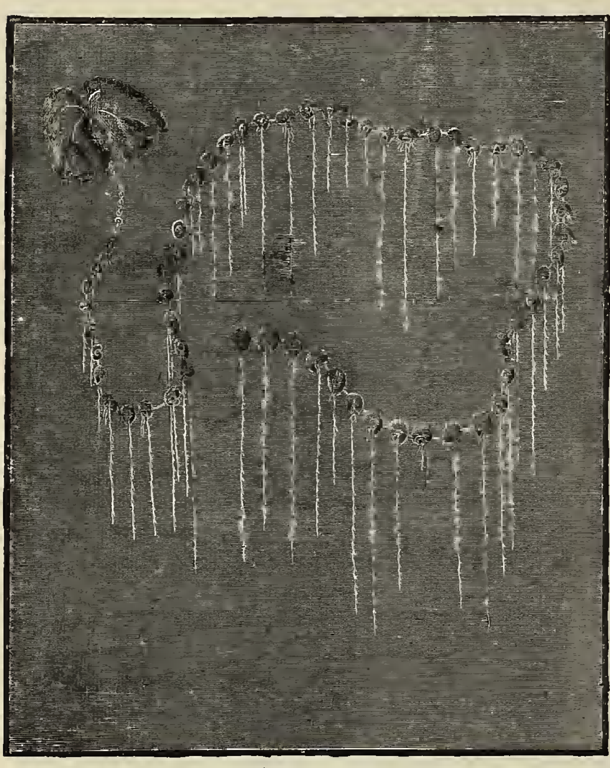
PHYSALIA UTRICULUS.

Physaliæ are found in vast multitudes, and about 120 species exist, and they are amongst the most graceful and beautiful objects of the ocean and large seas.

The sub-order Calycophoræ have the hydrosoma, or swimming body, propelled by special swimming bells, or nectocalyces, each of which resembles the bell of a medusa without the root-like processes. The cavity of the bell is muscular, and the pedicle of attachment has a process of the body-cavity branching into canals. The bells may be retracted into the mass of the body, which is flexible, unbranched, filiform, and walled. *Praya diphyes* has two small rounded swimming sacs, nearly alike, and they are placed opposite and at the end of the body. They have groove-like processes for retraction, and the male and female individuals are attached to the same body-mass, or cœnosarc. Diphyes is also a genus of the sub-order, and has two large natatory sacs, one placed, as it were, within the bell of the other.

Physophora hydrostatica, of the Mediterranean, belongs to another sub-order—the Physophoræ—and has a rather twisted floating body, whose natatory vesicles are in two rows. Below these is a crown of tentacles surmounting the colony of nutritive, generative, and filamentary zooids.

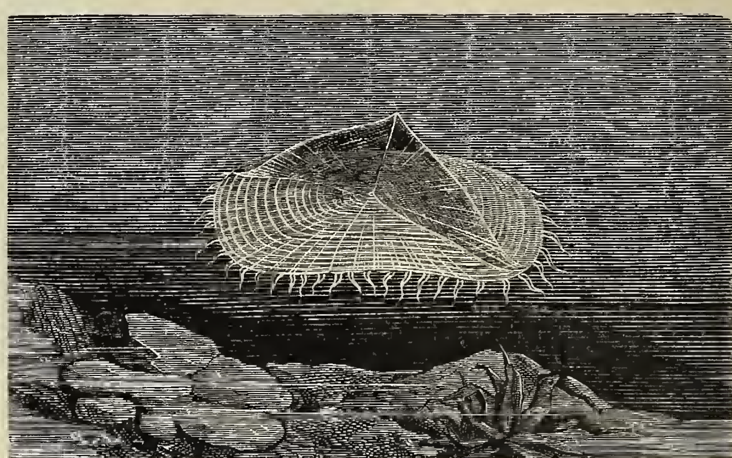
The little Velella, of the sub-order Discoida, has been compared to a little raft with an obliquely placed upright sail; the raft has its system of canals, and the thin membranous sail is the air-sac. It is cartilaginous, and the concentric tubes found within open externally. Below the disc are the nutritive and generative zooids, and there is usually a large polype in the midst of this crowded submarine colony. There are tentacles on the edge of the disc, which may be bright blue, purple, or brown in colour. It sails along with its upright membranous part, and is kept up by the air canals. The generative zooids produce medusæ, which become free. L. Agassiz describes the medusa of *Velella mutica* as a long bell, with a short proboscis in the upper part of the cavity, which is connected with the outside by a tubular opening. Eggs are the product of the medusæ, and they develop into Velellæ.



PRAYA DIPHYES.

ORDER HYDROIDA.

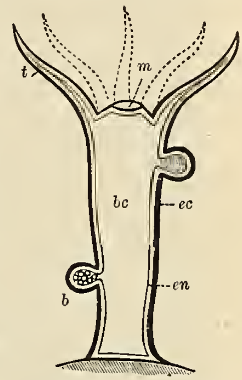
The fresh-water polype is a common name for several species of the genus Hydra, which are to be found in ponds and slow streams, hanging to the under surface ot floating leaves and upon the stems of water plants. If in the summer time a glass jar is filled with clear pond water, and some of the duck-weed also, minute bodies, like pieces of green sewing silk, about the sixth of an inch long and very slender, will be seen on the sides of the vessel, or on the weed, beneath the water. On using a low magnifying power, the little object is seen to be fixed by a small sucker-like base, and to have a cylindrical body, terminating in a crown of feelers, or tentacles, six to ten in number, and shorter than the body (*Hydra viridis*).



VELELLA LIMBOSA.

It usually hangs downwards, and the tentacles stretch out, curve, expand, and contract, whilst the body elongates, and often, on a slight alarm, contracts, and becomes more or less globular in shape. A minute crustacean swims along close to the Hydra, and one of the tentacles touches it. The movement of the living prey is arrested at once, the tentacle adheres to it, and then the whole crown of feelers comes to help, and the morsel is dragged to the mouth and slowly passes into the body. There, enclosed in the visceral cavity, the victim is slowly digested, and the undigested matter is, after a time, returned by the mouth. Tired of its position, the Hydra may be seen to bring its crown of tentacles

close to the glass or weed by bending the body. It fixes itself by the tentacles, lets go the sucker end, and remains for a second or two, or more, head downwards. The original base moves forwards, the body bends, and applies it to the supporting substance, to which it becomes adherent before the tentacular extremity is set free. By this process of creeping some progress is made. But often the Hydra gets as close to the top of the water as it can, and suddenly casts its body loose and turns the base upwards, just beneath the surface. Waving the tentacles about, the process of swimming is carried out, and the expansible disc, by floating on the water, assists.



DIAGRAMMATIC SECTION OF HYDRA.

ec, ectoderm; *en*, endoderm; *m*, mouth; *t*, tentacles; *bc*, body-cavity; *b*, bud.

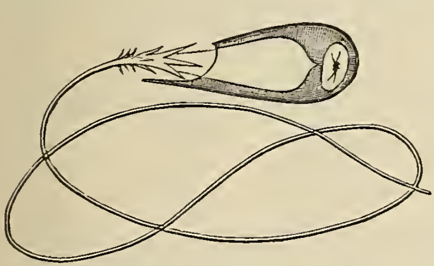
After a while a little nodule appears on the body of the well-nourished Hydra, and it grows outwards, and soon a crown of tentacles appears at the free end. This is a bud which resembles the parent. A second may grow, and thus the stem and buds constitute a little colony. But the buds drop off, and, having developed a base, become free, and take care of themselves. In some instances the Hydra diminishes in its girth at one spot, and at last breaks off there. The free portion develops a base, and the fixed part a crown of tentacles, and thus two individuals are formed by a process of fissiparity. In the autumn, eggs escape from the outer tissues, having been previously fertilised, and their central mass forms a clear ectoderm and a darker endoderm. This escapes from its cover, and is set free. No cilia are on it, and it gradually develops tentacles.

In the adults the outer tissue, or ectoderm, of the body is continued up unto the tentacles, and consists of large nucleated cells, from whose bases filaments are continued inwards. Surrounding these neuro-muscular cells are others which contain nematocysts. Moreover, minute points project from the surface cells.

The inner tissue, or endoderm, which lines the visceral cavity and the inside of the tentacles, contains cells, with amœboid movement, and spaces in the midst called vacuoles. Some have long cilia. The food passes down an opening in the midst of the bases of the tentacles, and reaches a sac-like stomach, and particles of it get into the vacuoles, and are digested there.

Vertical fibres and amœboid cells exist between the layers of the body, or, rather, there is an inter-cellular substance common to both layers.

One of the most extraordinary gifts of the Hydra is its power of reparation of injuries, and reproduction of new individuals out of portions into which it has been accidentally or naturally divided. If a tentacle be cut off, an entire animal is formed out of it; if the body is cut in half, it will join together again if the parts are placed together, and if not, two individuals will result; if parts of one individual are placed on the cut surface of another, they will grow together; and if the body be turned inside out, the old ectoderm takes on the digestive power, and the former endoderm that of the skin.



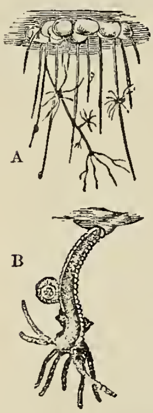
NEMATOCYST OF HYDRA VIRIDIS.

Another common Hydra is the brown one (*Hydra fusca*), and its tentacles are longer than the body.

These interesting and readily obtainable creatures are species of a genus which belong to a family—the Hydridæ of the sub-order Tubularia, classified under the great division or order of the Hydroida. The Hydroida differ very considerably from the other orders already noticed, in one part or during the whole of their existence. They are very plant-like and stationary during the whole of their existence, and they sometimes develop buds which become free-swimming medusæ. These reproduce ova, which become like the fixed or parent stock. The exceptions to this rule are few, and the characters of the Hydra are rather exceptional.

The fixed polypes of one of the sub-orders, the Trachomedusæ, are not known, and they may not have an alternation of generation; and all the medusæ of the plant-like or stationary forms have not been discovered. Moreover, different genera of the Hydroida may have medusæ, which present the closest similarity, and the medusæ alter much as they develop during growth. The polypes have

a simple internal structure, and may or may not be provided with a mouth and a gastric cavity. This is simple and without œsophagus and divisions, and is ciliated, as a rule. Tubes may pass from it in some large forms. The nervous system is neuro-muscular in the fixed forms, and there is a rudimentary nervous structure in relation to the marginal canal and lithocysts of the medusæ. The sexes are separate, and the colonies contain male and female stock, besides those destined for alimentation.



A, HYDRA VIRIDIS, ATTACHED TO DUCKWEED; B, MAGNIFIED; WITH A BUD.

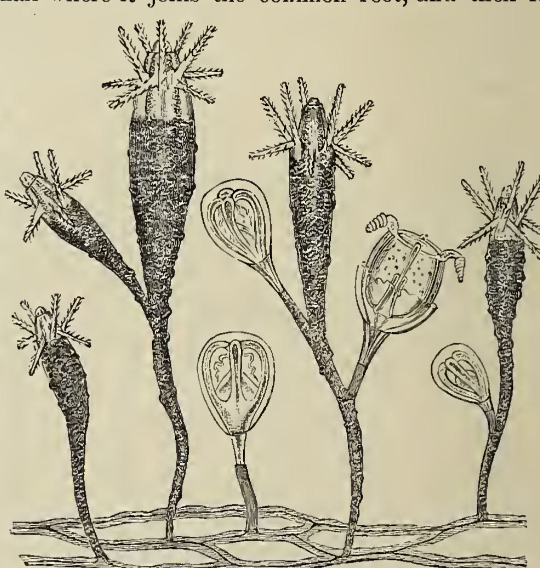
The Hydroida, therefore, consist of colonies of polypes, more or less dendroid or cespitose in shape, which produce sexual buds, which often bear free medusæ.

The order contains several sub-orders, such as the Hydrocorallinæ, the Trachomedusæ, the Tubulariæ, and the Campanulariæ, of which the last two are the more closely allied, and are very typical of the order.

SUB-ORDER TUBULARIA.

Dr. Allman found in the Firth of Forth, in the month of June, whelk-shells covered with a mossy-looking growth, which, on a slight magnifying power being applied, proved to be a number of polype-looking things, having their stems united at their bases by a set of roots, and having tentacles at the other end. Some of the stems were narrow where attached to the roots, and became smaller near their ends, which diminished in size, and resembled small cones. At the top of the cone is a small mouth, and just below it is a circle of six to ten tentacles, some projecting outwards, and others upwards and downwards. On the stem, but not reaching up as far as the tentacles, is a skin roughened with particles of sand, and a more delicate one extends to the mouth. Some of these stems had an offshoot made like themselves. They were about two lines long. Very contractile on irritation, and having the power of killing prey with nemotocysts, which occur in bundles on the tentacles, these stems receive food and digest it, and are the nourishing parts of the colony.

A second kind of stem exists, but it is very small where it joins the common root, and then it becomes suddenly globular, and has neither opening nor tentacles when small. This kind has nothing to do with nutrition, but is part of the reproductive apparatus. For in June the globular mass enlarges, and becomes transparent, and after a while it bursts, and a small Medusa or Jelly-fish, egg-shaped at first, but growing more ball-shaped, escapes. This has two long tentacles on the edge of its umbrella, and the mouth within has four shallow lips. It is a pale reddish little thing, and moves after the fashion of larger ones. Leading a free-swimming life, and taking in food, it produces eggs which, after hatching, settle down, and each one becomes in the year following a colony of the stems just noticed. Such an animal belongs to the Hydroida, and from having the generative bud and tentacles of the stem uncovered by any special hood, it is called one of the gymnoblast group, or sub-order.*



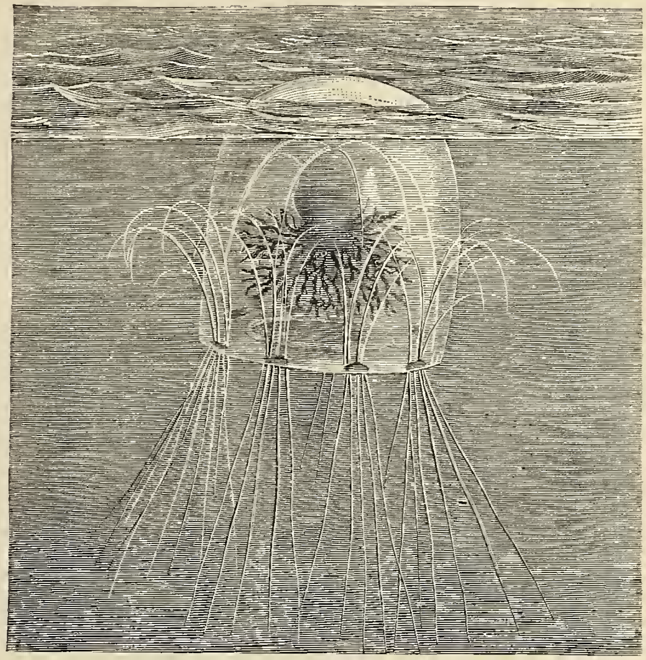
PERIGONIMUS VESTITUS. (*After Allman.*)

The species is *Perigonimus vestitus*, and the genus was named by Sars from the fact that sometimes the medusa buds are found around the nutritive stems (Greek, *peri*, around; *gonimos*, productive). It belongs to the family Eudendridæ, of the Gymnoblastea.

* Greek, *gymnos*, naked; *blastos*, bud.

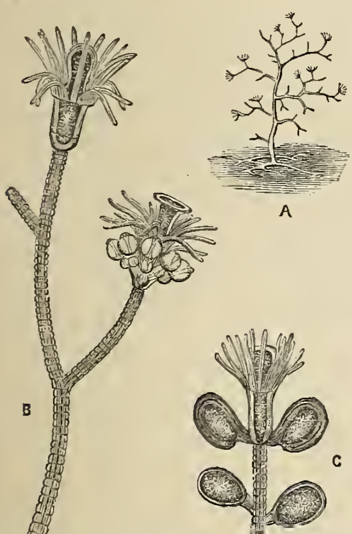
† Certain terms are employed to describe the Hydroids, and if the description of the species of Perigonimus be referred to, the terminology becomes easy of comprehension. The entire colony, with all its parts, stems, and roots, is the Hydrosoma (Greek, *hydra*, a monster; *soma*, body). The stems which are nutritive only form the Trophosome (Greek, *trophe*, nourishment;

Eudendrium has a species forming pretty little tree-like shapes in rock pools near low water spring tides on the southern coasts of England. It* is about three-quarters of an inch in height, and consists of rootlets and a stem with regular branches, and has the nutritive and generative zooids on it. The outer tissue, or perisarc, is distinctly marked with rings, and is annulated, and there are about twenty tentacles, some looking upwards and others downwards. The gonosome has male and female sacs in whorls, and they are placed just behind the tentacles or on the stem lower down. Some small medusæ of the genus *Lizzia* belong to this group.



LIZZIA FLOATING BENEATH THE SURFACE.

A third genus is Hydractinia, and it is remarkable for its resemblance to Millepora, one of the Hydrocoraliinæ, but it is without the hard calcareous base of this last.



EUDENDRIUM INSIGNE. (*After Allman.*)
A, colony, natural size; B, male colony, magnified; C, female bearing gonophores, magnified.

Hydractinia has several species, and it was at first taken to be a Bryozoon, from the horny spinous crust which it forms on the surface of empty univalve shells. It forms numerous colonies, and the hydranths are claviform, and arise from the surface of the common base, or hydrophyton. There is a crown of tentacles, which are filiform, and it encircles the conical mouth. The generative buds are on smaller polypes, which are without mouth, and end in globular clusters of thread cells representing the tentacles of the hydranth. The generative buds cluster around this polype, which is called a blastostyle, and some contain, around a central body, the ova, and others the male elements.

A common species (*Hydractinia echinata*) is found on the shores of England, France, and Belgium, and covering more or less dead univalve shells inhabited by Hermit crabs. It has, near the margin of the base, spiral appendages, cylindrical in shape, and very contractile and movable. They twist and untwist with great vivacity.

The genus Podocoryne is not very unlike the last mentioned, but all the polypes are tentaculate.

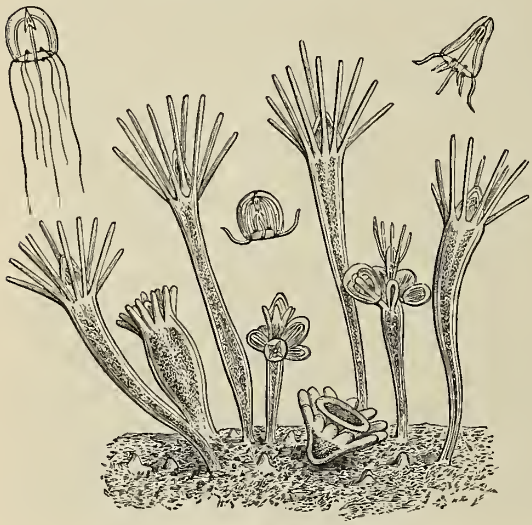
soma, body). The buds which produce the medusæ, or the generative part of the colony, are the Gonosome (Greek, *gonos*, offspring). When the Trophosome branches, or has offshoots, each one is a zooid, and the proper nutritive zooid, which has a mouth and digestive cavity, is the hydranth (Greek, *hydra*, hydra; *anthos*, flower). The mouth is at the end of a cone, which is called the hypostome (Greek, *hypo*, under; *stoma*, mouth). The common basis of the Trophosome, by which the zooids are connected, is the hydrophyton (Greek, *phyton*, a plant), and the end of the hydrophyton, or root, is the hydrorhiza (Greek, *rhiza*, a root). All the hydrophyton between the root and the hydranth is the hydrocaulus (Greek, *kaulos*, a stem). The bud, or zooid, which contains the reproductive elements, is a gonophore (Greek, *gonos*, offspring; *phoreo*, I bear).

A planoblast (Greek, *planos*, wandering) is a generative bud, fit for a free locomotive life; and a blastostyle (Greek, *stylos*, a column) is a columniform zooid, destined to give origin to generative buds. Umbrella is a term for the gelatinous bell of a medusa; the manubrium is the part carrying the mouth; and the velum (a veil) is a membranous perforated diaphragm, which stretches across the orifice of the umbrella which communicates with the external water.

* *Eudendrium insigne.*

The buds on the generative tentacle-bearing parts develop into medusæ, which are deep bell-shaped. Each has the outer surface dotted with scattered thread cells, and there is a velum or membrane between the margins of the bell with a central opening. There are from four to eight marginal tentacles with bulbous bases destitute of ocelli. Four radiating canals are to be seen, and the mouth or manubrium is small and four-lipped.

Other Tubularians belonging to the family Clavidæ may be instanced by a very pretty species* belonging to the genus Syncoryne,† which is characterised by having numerous club-shaped hydranths united in a common colony. The tentacles, moreover, are scattered on the clubs and are not in whorls, and the gonophores are in the form of medusæ, with four radiating canals and four marginal tentacles. The little species is of a deep orange colour, and this tint is found on the medusa buds as well as on the hydranths. The little colony is about half an inch in height, and the trophosome has its tentacles knobbed and along the length of the club-shaped part. The medusa buds (gonophores) are in short peduncles, just below the tentacles. These are developed in April, and when the medusa is ready to escape it has four very extensible tentacles at the margin of the umbrella, and is nodulated with clusters of nematocysts. A distinct ocellus is on the base of each tentacle. It is, of course, not covered with a membrane, and is "naked eyed." The mouth is short, and there is a membrane or velum extending across the opening of the manubrium with a central opening in it.



PODOCORYNE CARNEA. (*After Allman.*)

Allman found a branching Hydroid in fresh water, and it has since been proved to live in lakes, docks, and rivers in this country generally. It seeks the shade, and is found under logs of wood and attached to the sides of dark cisterns. The whole colony may be one inch and a half to three inches long, but the hydranths continually contract and enlarge, and are very changeable in shape. It is called *Cordylophora lacustris.*

The gonophores which produce the young on the stem are long and oval in shape, and these escape from them, not in the form of medusæ, but as long ciliated bodies or planulæ. The planula or embryo settles down, loses its cilia, and becomes a stem and hydranth.

The last family to be noticed contains a very large and common species belonging to the genus Tubularia.‡ The characters of the family are that the hydranth has two whorls of tentacles, one in front of the other. There is a chitinous investment, like a tube, to the root-stem, and the gonophores are in the form of fixed sporosacs, in clusters, reaching down like branches of currants, below the crown of tentacles. These are seen in all stages of growth, and the large ones are the lowest. A zooid escapes from each in the shape of a cylindrical stem with a stellate root and a crown of tentacles, and it grows into a hydrosome. The calycles of the mature form are apt to bend down; one drops off and a new one starts from the wound.

They are very beautiful objects, and the cylindrical stems rise without a branch to the height of several inches, and the tentacular head is scarlet or crimson in colour. Its longer tentacles spread out and retract, and the gonophores droop gracefully amongst them. Spring and summer are the times when this species of the Atlantic and British seas is in perfection, and it is during its most active growth that the tentacular heads are cast off and renewed.

SUB-ORDER CAMPANULARIA.

The sub-order of Hydroids, which are not only furnished with a chitinous investment over

* *Syncoryne pulchella.* † Greek, *syn*, together with; *koryne*, a club. ‡ *Tubularia indivisa.*

the stems and roots, but have also a hard, transparent, horny-looking structure which environs the top of the polype and protects the tentacles, are the Campanularia. The hydranths thus furnished can retract almost completely in this calycle, and hence they are called Calyptoblastea. The gonophores arise regularly from the gonosomes, which have neither tentacles nor mouth, and some are sessile, and others become free medusæ. Most of these medusæ have marginal vesicles, and produce the sexual elements in the radial canals. The calycles take on most graceful forms, resembling little vases, and often have ornamented borders. The horny cup of the hydranth or nutritive individual or part is called the hydrotheca, and that enclosing the generative buds is called the gonangium.

In many species the aperture is furnished with an operculum, which opens to allow of the passage of the polypite, and closes on its retreat. It is a very effective contrivance, and exhibits two or three principal modifications. In some instances the margin is cleft into a number of pieces, which converge and meet in a point, and form a more or less conical lid. In others the cover is a membranous extension of the walls of the calycle, which falls into plaits or folds when the polypite withdraws, and so roofs over the opening.

THE STRAW TUBULARIA (*Tubularia indivisa*).

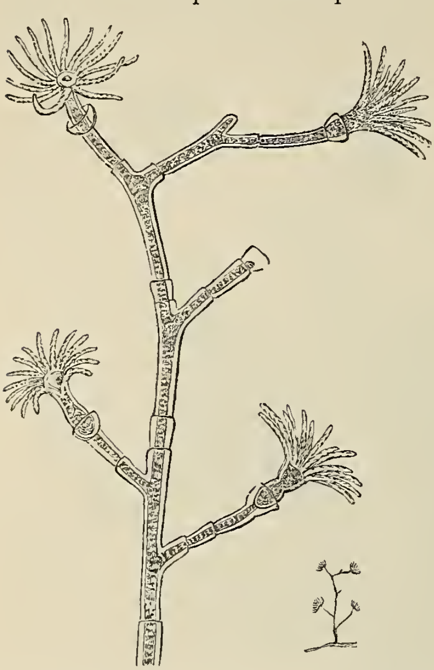
FAMILY SERTULARIIDÆ.

Amongst the Sertulariidæ the calycle has a lid or operculum within it, a little below the orifice. It is attached to the interior surface, on one side, and seems to be a continuation of the inner layer. It shuts down over the polypite when it withdraws itself. When the polypite emerges, it slowly pushes the valve back, and keeps it erect so long as it is exserted; on its retreat, which is as quick as light, the lid flies back to its place. (Hincks.) This family has the hydrothecæ sessile, and more or less inserted in the stem and branches. The polypites are completely retractile, and have a single wreath of filiform tentacles round a conical proboscis, and the gonozoids are always fixed.

The great Tooth Coralline is one of these, and belongs to the genus Sertularella. The plant-like, branching, jointed stem is rooted by a creeping stolon, and the calycles are decidedly alternate, and have a toothed orifice and a convergent operculum. The reproductive calycles (gonangia) are always more or less ringed transversely. It is of a bright straw colour when living, and is a common shore and deep-water species.* The Tricuspid Sertularella is of a delicate habit, light brown colour, and grows

* *Sertularella polyzonias.*

to the height of two inches. The calycles are narrow and cylindrical, and the aperture has three denticles. The reproductive capsules are large and very deeply grooved or cut. It is a North Sea form.


PLUMULARIA HALECOIDES (YOUNG). (*After Hincks.*)

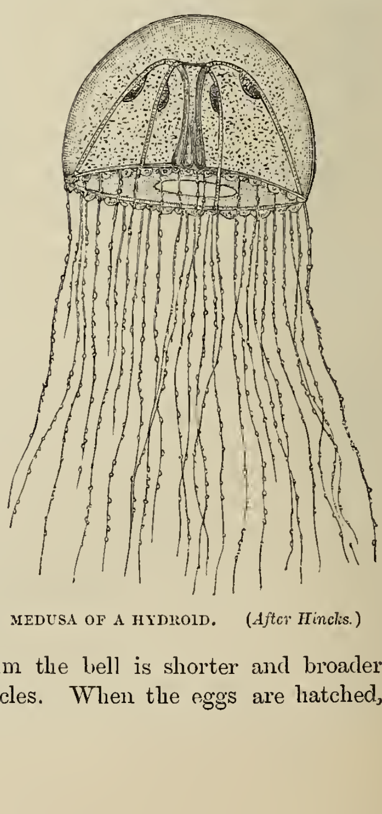
The genus Sertularia has the hydrothecæ in two series along the stem, and they are opposite or alternate, without an external operculum. The gonothecæ are large, scattered, and have a simple orifice.

The Sea Oak Coralline* is a common example, and covers the fronds and stems of the larger seaweeds on the British coasts. It is of a dusky horn-colour.

FAMILY PLUMULARIIDÆ.

The hydrothecæ are sessile, and on one side nematophores exist, and the polypites have a single wreath of filiform tentacles round a central proboscis. The reproductive zooids are always fixed.

Plumularia pinnata attains the height of four or seven inches, and its stems are tall and whitish, and jointed irregularly. The nematophores are sessile and minute, one being below each calycle. The gonothecæ form a double row along the main stem, and have a number of spinous projections at the tip. It is a common species on shells, from low water to greater depths. The nematophores consist of an extension of the body, which may be tubular, or cup-shaped, or conical, open at the upper extremity, and enclosing a granular mass, in which large thread cells may be imbedded. Some are simple, and the chitinous cup consists of a single chamber, much adherent by its side, and when they are compound there is a tubular portion below, expanding into a hemispherical cup. Some are pedunculate and others sessile. They occur on various parts of the colony, and are usually present in numbers about the hydrothecæ; and in the genus Aglaophenia every tooth on the crested ribs of the case, or gonangium which protects the gonophore, is formed by one of them. The soft granular mass filling the nematophore has the power of emitting and retracting very extensile and changeable processes.


MEDUSA OF A HYDROID. (*After Hincks.*)

In the genus Ophiodes remarkable thread-like organs are found in great numbers on the creeping stolon, and one is stationed close to the polypite. Each resembles a delicate tentacle, has its narrow base surrounded by a cup-shaped prolongation of the outside tissue of the colony, and is terminated by a knob with thread cells.

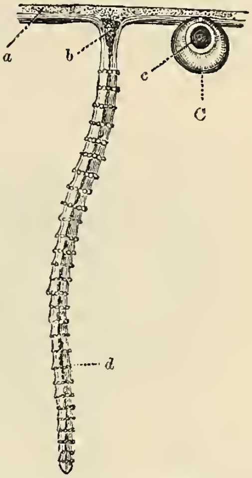
In the family Campanularia the hydrothecæ have a ringed peduncle, and the crown of tentacles is below their projecting mouth-trunk. The gonophores are sessile or may become transformed into medusæ, some of which are flat and others bell-shaped.

The family Thaumantidæ has medusæ in the shape of long bells with a short peduncle, the mouth being lobed. There are two long and two rudimentary tentacles in the genus Lafoea, and four radial canals, which contain the reproductive organs in the form of ribbon-shaped masses. In the genus Melicertum the bell is shorter and broader at the margin, and has a crowd of very slender irregular tentacles. When the eggs are hatched,

* *Sertularia pumila*

planulæ settle down and elongate, a sheath is formed around them and tentacles arise. By-and-by the stem branches, and a colony is established, the gonosome stems producing the medusæ in due time.

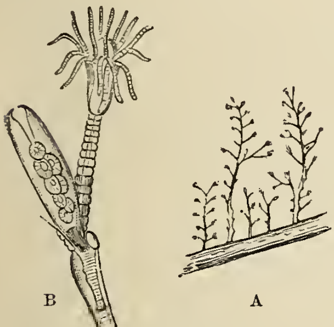
The Equoridæ are the last family, and the genus Zygodactyla (twin finger) is its type. The medusæ of this genus are from seven to eight inches in diameter and light violet in colour. The tentacles are long and fibrous, and dark violet, and can be contracted to a mere fringe. They often remain motionless in the water. It is an inhabitant of the North Atlantic and Northern Seas generally.



MARGIN OF A MEDUSOID.

a, circular canal; *b*, ocellus; C, sac or lithocyst; *c*, spherule of lime; *d*, tentacle. (*After Hincks.*)

In the genus Eucope the tentacles are well developed, and the calycular membrane which comes up to their bases diminishes in size until it joins the ringed tissue of the stem. On one side of this a long and rather fusiform projection exists, and it has a central body, around which medusa buds form. This gonophore permits the medusæ to escape. They are flat, with a little knob at first on the top, and a few short tentacles are around the disc. Really the knob is the proboscis of the mouth, and the little medusa turns inside out with ease.



EUCOPE DIAPHANA.

A, the colony; B, the young medusæ within the reproductive part. (*After L. Agassiz.*)

SUB-ORDER TRACHOMEDUSÆ.

The Trachomedusæ have a gelatinous disc, which feels decidedly hard to the fingers, and the margin is usually lobed. The tentacles are either rigid or else can move, and there are peculiar sense organs on the base of the tentacles, accompanied by lithocrysts, and sometimes by eye-spots. They do not pass through any colonial stage, and the eggs develop into a ciliated larva formed of two layers of tissue, and it has no stomach, but becomes elongated into two arms. After a while two other arms or tentacles are seen, and the central cavity and mouth. Reproductive organs appear, and then more tentacles. There are numbers of these Trachomedusæ in the oceans, and many genera have been distinguished.

In the fresh warm water (86° Fahr.) of the tank which contains the Victoria Regia in the Botanic Gardens of the Regent's Park, London, Mr. Sowerby found great numbers of minute medusæ moving with great vivacity, and preying on the minute crustacea. They were about a line to half an inch in diameter, and had nearly 200 tentacles and four radiating canals and a circular one. There was a velum, and the margin had many eye-spots. The manubrium is long and expanded below, and the tentacles are solid. The genus has been called by Dr. Allman *Limnocodium*, and Prof. Ray Lankester believes that probably it is one of the Trachomedusæ. It is probably the only instance of a medusa which can live in perfectly fresh water, and which dies in cold or salt water. Nothing is known about its origin.

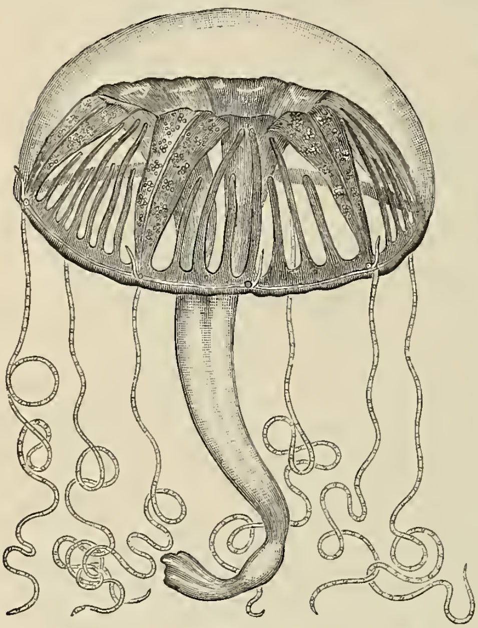
There are many families of this sub-order, and four may be especially noticed. The Trachonemidæ have the marginal filaments rigid and hardly movable, and the sexual organs develop in vesicular swellings in the eight radial canals, and some have a flat disc with club-shaped tentacles.

Some, like the Ægina, with rigid marginal tentacles, belong to the family Æginidæ. The stomach-pouches reach far towards the edge of the disc, and the sexual elements are produced by the derm of their sides. Sometimes there is no marginal canal, and four tentacles often exist.

The Geryonidæ have a large cylindrical peduncle environing the stomach. Four or six canals are in the umbrella, and extend from the bottom of the stomach to the radial canals in which the reproductive organs exist. Finally, the Charybdeidæ have the borders of the umbrella with tentacles and compound marginal corpuscles. Ramified canals come from the processes of the stomach. They are dwellers in the Mediterranean and Atlantic.

ORDER HYDROCORALLINA.

The hard, stony, coral-looking substances dotted over with minute pores, and having, within, a tubular structure crossed by platforms or tabulæ, are called Millepores. They are reef-builders, and contribute to the solidity of the coral reef structure, dwelling, however, in the warmest waters of the tropics. Formerly classified with the true Corals, they are now, owing to the researches of L. Agassiz and Prof. H. N. Moseley, placed among the Hydroids. The last-named and distinguished naturalist, after having carefully examined the anatomy and development of the Millepores, during the expedition of H.M.S. *Challenger*, has placed them in association with certain deep-sea calcareous skeletoned animals, called Stylasters, in a sub-order—the Hydro-corallinæ.



CARMARINA (GERYONIA) HASTATA. (ONE OF THE TRACHOMEDUSÆ.)

This is characterised by the presence of a calcareous base made up of channels formed by the ectodermal part of canals within them. The base is covered with a continuous layer of derm, from which zooids of two forms arise: one with a mouth and gastric cavity—a gastro-zooid;* the other with tentacles and no mouth—a dacty-lozooid;† they are retractible and lodge in the pores or outer-chambers of the hard part.

FAMILY MILLEPORIDÆ (*WITHOUT AMPULLÆ*).

The species of the genus Millepore are found on Coral reefs, and the dense white substance forming their usually visible portion is of stony hardness, and is marked with numerous pore-like openings, small and sometimes arranged in groups. A dried piece looks worm-eaten on the surface around and between the pores, and these lead down to long tubular cavities, across which flat layers of the same mineral, carbonate of lime, which forms the hard substance, generally stretch one over the other. These are called tabulæ, and they separate chambers, the upper one being free above and open on the surface, and its floor is the last-made tabula. Between the pores and their downward tubular prolongations is a curious hard structure made up of a network of hard tissue, which gives the porous or worm-eaten appearance to the outside. Louis Agassiz and H. N. Moseley both have discovered and described the soft parts on and within this dense white substance, which much resembles, but is not, white Coral. A thin living film covers the whole surface, and a thin downy layer is observed over all, and it consists of minute feeler-like projections arising from the pores. Arranged as these pores are more or less in circlets around a central one, their tentacles differ. The central larger one has a short body provided with a mouth, and it is a cylindrical growth with from four to six short tentacles in one whorl at its top, just below the mouth. Each of these tentacles has a knob at its tip, composed of nematocysts. The small mouth opening is circular in outline, and a little lower down is a cruciform slit environed with gastric cells, bladder-like and transparent. The other bodies surrounding this one, and coming forth from the circlet of pores, are long and slender, cylindrical and tapering. They bear tentacles at regular intervals from top to bottom, each of which consists of a short cylindrical stem with a knob.

No mouth or stomach exists in these long bodies, and their office appears to be to catch food and convey it to the short body with a stomach, in the middle of the circle. All disappear on very slight shaking of the hard mass. The network of the hard substance, supporting these structures, contains soft parts and numerous tortuous canals, and some of these are on the surface and connect the pores together. The hard structure, composed of fibrous-looking carbonate of lime, is produced by the outer skin or ectoderm of the animal, and is nourished by and formed from the digested food, which contains more or less carbonate of lime.

* Greek, *gaster*, stomach. † Greek, *daktylos*, finger; *zoon*, animal.

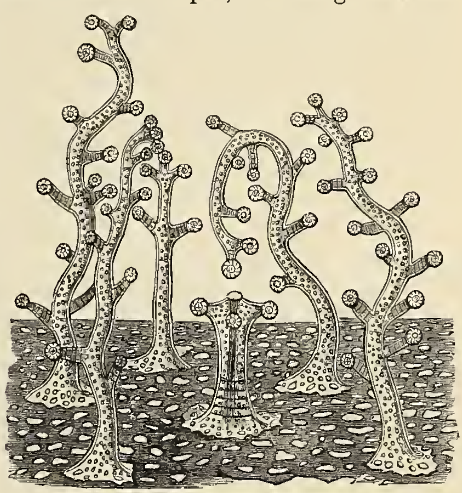
The stomach and finger zooids contain muscular fibres, and the nematocysts or thread-cells have a spiral within them, with part of it jagged with a thorny part. Others have three barbs on the thread.

The hard part of the Millepore is called the cœnosteum. Unfortunately, the method of reproduction has not been ascertained by Prof. Moseley, to whom we owe the very exact description of these interesting things, which were formerly, before Agassiz saw the zooids, considered to be true tabulate Corals. Certainly it is only the part of the cœnosteum above the uppermost tabula that is alive; all below was so once, and has died.

FAMILY STYLASTERIDÆ (*WITH AMPULLÆ*).

These have the pores with a style or calcareous spiny projection. Ampullæ, or blister-like swellings on the surface, contain the male elements and large planulæ.

The Stylasters were named after small red-coloured, more or less fan-shaped, branching coral-like substances, on which are numerous groups of pores surrounding central cavities, having a projection at their bottom. Until Moseley examined them, they were included in the Stony Corals, and the divisions between the pores were considered to be septa. He has proved that the family, which comprises many genera, belongs to the same sub-order as the Millepores. The hard part of the animal is composed of reticulations of tubes, and a gasterozooid occupies the central pore space, and dactylozooids the surrounding circlet of pores. The hard part consists of carbonate of lime to a considerable extent, and is formed by the deposit of it in the substance of the outer skin, or ectoderm, of the canals or tubes. The canals open into the pores, which are really cylindrical pits, and at the bottom of each are a few large canals and their openings. Some genera have a projection, or style, more or less brush-shaped, on the base of the floor of the cavity for the gasterozooid, and resting on a partition or tabula, of which there may be more than one. Small, more or less rounded, projections occur on the surface of the hard part of the animal, and they are the domes covering spaces. These open by slits or get very thin at the surface, and contain the male reproductive elements, or a most remarkable worm-like embryo, which is termed a planula. The planula is large and cylindrical, and being curled up, is larger than the cavity in which it has developed out of an ovum; and this cavity is large in relation to the circlet of pores in some genera. A mature planula is a quarter of an inch in length, and has a transparent gelatinous-looking outer skin, or ectoderm, and a dark-coloured inner, or endoderm. It looks like a worm, and is probably covered with cilia, and there are polygonal markings on the body, and nematocysts. No internal organs exist, and this young form is solid within. It escapes and settles down after leading a free-swimming life, but how the future growth proceeds is not known.



MILLEPORA. (*After Moseley.*)
The gasterozooid is central, and the dactylozooids are around it.

The dactylozooids of all the genera of the family have simple tentacles, which retract, and the gasterozooids are flask-shaped, and may or may not have club-shaped tentacles on them.

These interesting Hydrocorallinæ are found very widely distributed from 10 to 750 fathoms' depth in the North and other parts of the Atlantic and the Pacific Oceans. The West Indies, the coasts of Brazil, and the Japanese Seas are common localities. They may be arranged in two groups. In one the pores occur in regular circlets, or cycle systems, and the genera may again be subdivided into those which have styles present at the bottom of the gasterozooid, and also of the dactylozooid pores. Stylaster and Allopora belong to this subdivision. Of those with styles only present in the gasterozooid pores, Stenohelia is an example; and of those without any styles, Astylus and Cryptohelia are examples; the last-named genus has a remarkable lip in front of the circlet of pores.

In the second group, the pores for the dactylozooids are either of one or two kinds, and a group of genera belong to each. Pliobothrus and Errina are examples of the first, and Spinipora of the latter condition.

Fossil Hydrozoa have been discovered, some without doubt analogous to recent forms, and others not so. Impressions of medusæ have been found on the Solenhofen stone, and they were Rhizostomidæ. The Graptolites or Rhabdophora are fossils in the shape of long, narrow, toothed (at the side) bodies, single or combined. They are found in the Lower Silurian, and die out before the end of the Upper Silurian group of strata. Two principal forms exist: those with one row, and those with two rows of cellules; and in Rastrites the cellules are separate, and not overlapping as in the others. They may have a central disc or prong-like process at the end, with a central solid rod. The cellules analogous to the calycles of Sertularians probably contained structures resembling nematophores.

The Hydrocorallinæ of the Millepore division have no satisfactory fossil species; but there is a doubtful form in the Cretaceous rocks. Probably most of the family Favositidæ, usually called Tabulate Corals, were hydroids, and many of the corals called Rugosa.

A fossil, with a root-like expansion, hollow stem, and tentacles, surrounded originally by a calcareous investment, is found on the face of the fronds of a Carboniferous Bryozoon, Fenestella nodulosa. It has been named Palæocoryne—of the Hydroida.*

GROUP ZOOPHYTA.

CLASS HYDROZOA, OR HYDROMEDUSÆ.

Order.	*Sub-order.*	*Example.*
Ctenophora	Globata	Pleurobrachia.
	Lobata	Bolina.
	Cestidæ	Cestum.
	Eurystoma	Beroë.
Discophora, or Acalephæ	Monostoma	Aurelia.
	Rhizostoma	Rhizostoma.
	Calycozoaria	Lucernaria.
Siphonophora	Physophora	Physophora.
	Physalia	Physalia.
	Calycophora	Diphyes.
	Discoida	Velella.
Trachomedusa	Trachomedusæ	Ægina.
Hydroida	Tubularia—Gymnoblastea	Hydra.
		Perigonimus.
		Eudendrium.
		Hydractinia.
		Syncoryne.
		Tubularia.
	Campanularia—Calyptoblastea	Sertularella.
		Plumularia.
		Campanularia.
		Eucope.
Hydrocorallinæ		Millepora.
		Stylaster.
		Cryptohelia.

CHAPTER II.

THE ANTHOZOA.

Zoantharia and Alcyonaria—Characters—THE ZOANTHARIA—The White Stony Corals or Madreporaria—Structure—The Coral—Development—The Reef-builders—Coral Islands—MADREPORARIA APOROSA—Turbinolidæ—Oculinidæ—Astræidæ—Eusmilinæ—Euphylliaceæ—Stylinaceæ—Lithophylliaceæ—Astræaceæ—Cladocoraceæ—Fungidæ—MADREPORARIA PERFORATA—Eupsamminæ—Poritidæ—Other Groups of the Madreporaria—ANTIPATHARIA OR SCLEROBASIC ZOANTHARIA—ACTINARIA OR MALACODERMIC ZOANTHARIA—Characters—Actinidæ—Minyadinæ—Actininæ—The Sea Anemones—THE ALCYONARIA—Characters—Helioporidæ—Pennatulidæ or Sea-Pens—GORGONIDÆ—Red Coral—Formation—Gorgoninæ—Characters—Various Genera—Alcyonidæ—Distinctive Features—Organ-pipe Coral—Alcyoninæ—Dead Man's Fingers—Classification of Anthozoa.

THE CLASS ANTHOZOA.

THE White Stony Corals, Sea Anemones, and Antipatharia form one order of this class, the Zoantharia; and the Red Coral, the Tube Coral, the Isis, and the Alcyonians are a second order called Alcyonaria; and all of these familiar and beautiful objects merit the name of flower-like animals, from

* The principal works on the Hydrozoa, quoted in this article, are those of Allman (Ray Society), Hincks, and Claus.

their externaal spect. All have a home in the sea or in brackish water, and are usually brilliant in colour, radiating in their construction, have tentacles around a mouth which leads to a stomach, and this opens into a large lower cavity, called the perigastric. This communicates with the hollow tentacles, and has the reproductive organs in it. Portions of it are folded at the sides longitudinally, and projections of its membrane, called mesenteries, develop on and within them the ova and spermatozoa. The ova and young escape by the mouth as free ova, or as planulæ hatched from them, and not as medusæ. There is an outer skin, or ectoderm; an inner in relation to the stomach, the endoderm; and a tissue between, the mesoderm; and this last secretes, in some, a hard and even calcareous skeleton. The soft structures are usually very contractile, and they contain cellular structures, muscular fibres, much connecting tissue, and scanty, rudimentary nervous elements. There is no special circulatory, respiratory, or excretory system. But the ciliated cells of the outer and inner derms move water over the surface; and in some of the Corals, with a great number of individuals collected in one mass, there are evidences of a water system, which appears to regulate the symmetry of the whole. The derm is crowded with nematocysts, or thread cells, different as a rule in their construction from those of the Hydrozoa; but some have spiny barbs on the thread, and this is often invaginated more or less before extension. Large and small cells are also present, containing glairy mucus, which escapes on pressure, and colouring matter. The muscular fibres are delicate, without striæ, and are longitudinal and tranverse, or encircling. The whole soft structure appears to have a power of general or amœboid movement.

ORDER ZOANTHARIA.

The first sub-order of the Zoantharia is that of the White Stony Corals, or Madreporaria, and the members of it, very numerous in genera and individuals, live on the floor of the sea at all depths down to 3,000 fathoms, and cling to the shore from water level to twenty fathoms. Those which form Coral reefs come under the last assemblage, and the more solitary and simple deep sea Corals belong to the first. All contain in the mesoderm a quantity of hard matter, composed mainly of carbonate of lime in a fibrous or long crystalline condition, called Aragonite; and externally a simple kind will resemble a Sea Anemone. There is a range of tentacles, or more than one, on the top of the body, and a disc within the circle of tentacles, in the midst of which is a small mouth. A coloured tissue, like that of the outside of the tentacles and disc, covers the outside of the body, which generally assumes a cup-like form, or may be flat, bell-shaped, tubular, or compressed like a fan. The disc is marked with coloured lines that appear to radiate from the mouth, and if it is touched with a hard pencil it will contract slightly, and then beneath it is felt a hard structure, made up of a number of plates placed vertically, with their edges upwards. Spaces exist between these septa—interseptal spaces—in which there is a process of the under part of the disc, the mesenteric fold.

On stripping off the disc, the tops of the numerous septa are seen, covered with a filmy structure, and between each pair a soft mesenteric fold.

In the middle of the top of the Coral, and just under the opening of the mouth, is a hard projection, or axis (the columella), or else one does not exist, and the stomach cavity occupies the place. Above the columella, or in its place, is the stomach, lined with endoderm, and having the mesenteries radiating on all sides. Moreover, the tentacles, which are hollow, open into the interseptal spaces, so that the fluid of the stomach can pass around all the soft internal parts and up into the tentacles. The mouth in the disc has muscular sides, and is extensible, and it passes at once by a narrow space to the underlying digestive cavity. Nematocysts and glairy cells and ciliated cells abound in these parts.

The structures outside of the Coral, and which are continuous with those of the tentacles above, are thin, coloured, and abound with the same kind of cells as those just mentioned. The whole is under the influence of the moving water, and is aërated by it. Food, in the form of minute invertebrata, comes accidentally in the way, is stopped by the secretion of mucus or by the action of nematocysts, and is moved to the mouth by the tentacles, which grasp it, or by cilia, which simply move it onwards. The mouth opens, and the prey disappears to be digested, and the indigestible parts come forth from the mouth. The juices of the prey are circulated from cell to cell, and add to the bulk of the creature. But the calcareous parts of the prey—its shell, for instance, had it one—and a certain amount of the salts of lime held in solution by the water, are retained in the structures of the mesoderm of the body, and they form the hard Coral. The hard part of the Coral is produced by a deposition of carbonate of

lime in long or short and slender needles, or prisms, in the interstices of a peculiar connective tissue of the mesoderm. Hence these Corals are called Sclerodermic Zoantharia.

By placing a Coral in weak hydrochloric acid and water, effervescence of carbonic acid ensues, and the lime combines with the acid and is dissolved. At last a film remains of the shape of the Coral, and it represents the organic basis of it. An old piece of Coral, when cut in slices for microscopic examination, shows numerous radiating lines once occupied by the organic matter, and starting from them, on all sides, are bunches and masses of the prisms and irregular-shaped needles of carbonate of lime. In some Corals this texture is very dense, and in others very lax and porous; and in these last the texture of the hard part is very spicular, the ends being joined to form a kind of cellular structure. Hence the two great divisions of the Madreporaria: the Aporosa and the Porosa.

The hard parts of the Coral are remarkable for their regular radiation and numerical arrangement. They consist of a theca, or wall, which forms the cup of the Coral, which is closed below at the base, and open at the opposite end, at the calice. The septa, or vertical plates, pass from the inside of the cup towards the central axis. They are free above at the calice, and are sometimes not joined or attached to anything in the centre of the cup, but there may be a columella there, which starts from the bottom of the cup and grows upwards; or it may be formed by the ends of the septa. The interseptal spaces are open from top to bottom in some Corals, and in others there are thin pieces of carbonate of lime, which cross them more or less, and cut off the lower parts from the upper. The animal secretes these, and lives above the upper one. They are called dissepiments.

Outside the cup there are longitudinal ridges in relation to the septa within, which are called ribs or costæ; and they may be united by cross bars.

Some Corals are always simple and separate; others, and especially the reef-builders, are compound: that is to say, they propagate by budding from the parent, and then the buds form a succession of buds. A little projection appears on the side of a cup, and soon a few tentacles are seen there. It grows outwards and upwards, and resembles the parent. This is a bud. Other buds arise, and all grow upwards in a bush-like form, and then the buds begin to bud, and so on. There is a symmetry in the growth, and either this bush shape remains, or else structures are grown between the buds and the parent, connecting the whole in a solid mass, called exotheca. They are composed of layers of hard tissue arranged in cellular compartments or cross bars, so as to give great bulk, lightness, and strength to the Coral.

The Corals of all kinds produce ova, which escape from the mouth, and hatch into long ciliated bodies, or planulæ. These fix themselves and develop, becoming like the parent. The growth of the individual is accompanied by an increase in the number of mesenteries within the body, and of solid septa between each pair of mesenteries. Two great series of Corals develop septa differently. In one six septa are followed by six smaller, then twelve still smaller are formed, one in each of the already made interseptal spaces, and then twenty-four, and so on, the increase being by cycles in multiples of six. In another series there is a more or less distinct increase by fours, and the position of one or more of the first, or primary septa, is sometimes occupied by a groove. Or there may be a very numerous collection of septa, which appear to be without any rule, and to be alternate in size. In some Corals no definite order can be distinguished. Certain appendages to the septa, between them and the columella, are called pali, and they appear to have reference to a fresh circlet of tentacles.*

The first series are the Hexactinellids, and the second are the Rugosa.

The Corals which live on the southern coasts of England are simple, and do not form reefs, and others of the same genera are found in deep water on the floor of the great oceans. Pressure and temperature seem hardly to influence them, and they flourish in the great depths, in water not much above freezing-point. But the reef-building Corals require a warm sea, and highly aërated, pure sea water, containing an abundance of living things. These conditions are only to be obtained in those parts of the world where the surface temperature of the sea is never less than 68° Fahr., and indeed some Corals require a much higher temperature, such as 72° to 86°. Moreover, the necessary purity of water and freedom from sediments can only be got in the neighbourhood of islands standing in deep water. As the temperature of the sea diminishes rapidly with depth, that of 68° to 86° is not

* An individual Coral, perfect in itself, is a Corallum; a member or an individual which has budded or divided off, and yet still remains as part of a whole, is a Corallite.

maintained below twenty fathoms, and thus there is a downward depth limit to the reef-building Corals. They fringe certain islands within the West Indian, Atlantic, Indian, and Pacific Oceans, the Corals clinging on in great masses to the shore, some being uncovered a little at very low tide, and some extending to the depth of twenty fathoms. The growth is upwards, and outwards, or seawards, and sometimes to a considerable extent. Such a mass of Coral is alive on the top and where in contact with the sea; but all the supporting mass which once was alive is dead, and consists of a mass of hard Coral, united by exothecal structures, and much altered by the percolating water.

In some parts of the Pacific Ocean, an island is seen surrounded by a calm lagoon of sea water of no great depth, and in the offing is a more or less circular reef, with openings in it. This is a Coral structure which is growing, but does not extend deeper than twenty fathoms in the living state. But the foundation of the distant reef extends from it to the island, and underlies the living and dead mass of Coral. These are barrier reefs. In other parts of the great ocean simple rings of reef, called atolls, are seen. There is no mountain in the midst, but a lagoon. The fringing and barrier reefs are phases in the development of the atoll. The land was once surrounded by a fringing reef, and subsidence commenced. The Coral, ever growing, increased in bulk upwards, growing as the land sank, and this process gradually necessitated a shallow sea between the mountain tops and the reef. This barrier reef, still subsiding with the mountain, on which it hung amidst the waves, yet ever growing upwards, at last witnessed the total submergence of the land. An atoll thus formed is a vast mass of Coral covering a sunken island, the living Coral forming a ring around a lagoon, with openings seawards. This is the theory of Charles Darwin.

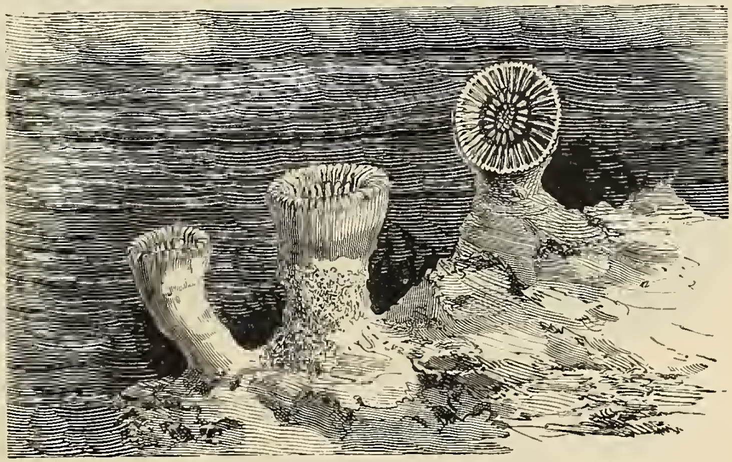
The most rapidly growing Corals live in the surf and most heated water on the outside of the reef, and the more solid reef-builders remain in quieter water, in the lagoon. Many simple Corals are found amongst the reef-builders, and live in company with a vast assemblage of Tubicolar Worms, Echinoderms, Anemones, and Crustacea; but the beautiful aspect of the reef, with its gorgeous colours of green, yellow, violet, and gold, is produced by the soft discs and stems of the Madreporaria and Sea Anemones.

The Madreporaria are very numerous in genera and species, and they may be divided into those which have the hard parts dense, and into those with a light skeleton, very porous in its nature, and reticulate in its construction. These divisions are those of the *Aporosa* and *Perforata*. A great group, now almost extinct, but which preceded those just mentioned in time, is that of the Rugosa.

THE GROUP MADREPORARIA APOROSA.

FAMILY TURBINOLIDÆ.

These Corals are usually simple and solitary, but some have offshoots in the form of buds, which resemble the parent. They are not united by exotheca, and there are no internal dissepiments in the interseptal spaces, exceptions to this statement being excessively rare.



CARYOPHYLLIA CYATHUS.

The common so-called Madrepore of the Devonshire coast,* and those which are dredged up out of moderately deep water in the North Atlantic, are common examples of the genus Caryophyllia, which do not usually increase by budding, but by the development of ova. Those species, which are fixed on to substances on the floor of the sea, often have a delicate outer layer of hard tissue, called an epitheca, and nearly all are very beautifully ornamented, and some

* *Caryophyllia Smithii* (Stokes).

have a spiny outside. This genus is the type of a sub-family* in which there is a row of pali, and it is found that the interseptal spaces, when the soft parts are washed away, are open throughout. One genus† increases by budding, and is therefore compound.

A sub-family which is but slightly represented now, and which had a great development in the Secondary and Tertiary ages, is that of the Trochocyathaceæ, and it has more than one row of pali, and consequently as many extra rows of tentacles. Several of its genera are now represented in the deep sea, and Deltocyathus is the most widely distributed, being found, moreover, at the depth of 2,250 fathoms.

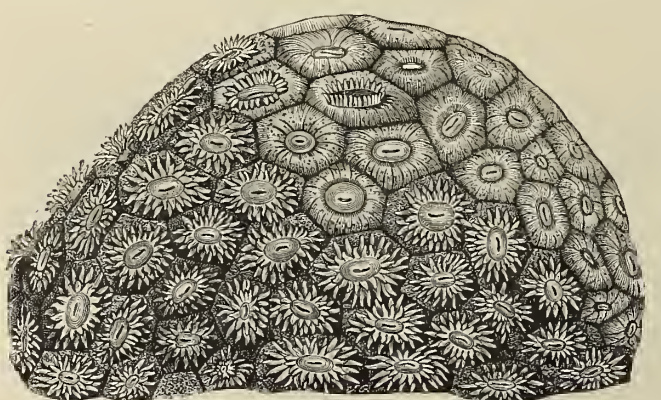
Another sub-family is that of the Turbinolinæ, and it is characterised by the simplicity of the hard parts, there being the cup or wall, septa, and costæ. Sometimes the columella exists, and an epitheca, but pali are not seen. Some of these simple forms are extinct, and the majority still live. They are divided into genera by the shape of the Coral, which, for instance, is compressed and fan-shaped in Flabellum and wedge-shaped in Sphenotrochus; and by the nature of the columella, which is styliform in Turbinolia and fascicular in others. Some, such as Blastotrochus, bud on the outside. Many of the species of this sub-family are dwellers on the floor of the deep sea, and the fossil forms are very numerous. The third sub-family is that of the Dasmidæ, and the only genus is extinct.

FAMILY OCULINIDÆ.

These are branching Corals, which bud on the outside of the stem, or on the edge of the calices, and have these last resembling, more or less, those of the family just noticed. There are, however, dissepiments in the interseptal spaces of some, and in the common *Lophohelia prolifera*, found on the floor of the North Atlantic, horizontal layers of hard tissue may cross the whole internal cavity, and are called tabulæ. Moreover, the lower parts of the cup fill up with carbonate of lime, and there is a general solidity of the branches. The genera are numerous, and many are extinct, whilst others inhabit great depths. A small sub-family, the Stylophorinæ, increase by the process of budding, or gemmation, but the hard tissue is not so compact as that of the others, and the columella is styliform.

FAMILY ASTRÆIDÆ.

This family consists of a vast number of genera, many of which are reef-builders; others are simple forms, and several are extinct. The hard parts have all the structures hitherto mentioned, and there are septa, costæ, a columella, endothecal dissepiments, epitheca, and buds. There is also exotheca in the compound forms. They are divided artificially into two groups: those with the tops of the septa plain—the Eusmilinæ—and those with serrations, or spines, on the tops of the septa—the Astræinæ. The first sub-family of the Eusmilinæ is a very ancient one, the Trochosmiliaceæ, and they are solitary Corals, cup-shaped, and with the internal dissepiments well developed.



FAVIA PALLIDA.

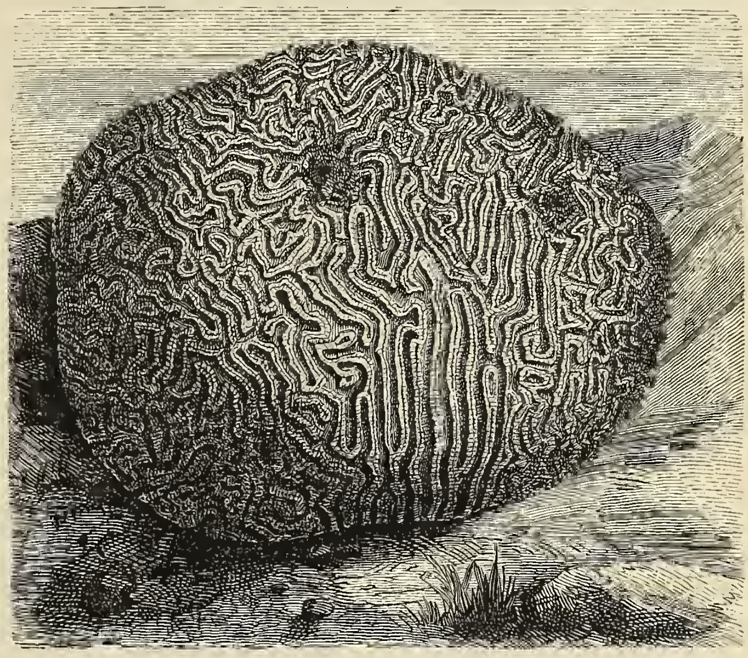
The sub-family Euphylliaceæ grow in bulk by fissiparous division of the calices. These elongate in one direction and divide, and the separate portions become isolated more or less above, but still remain parts of the original Coral. Some form tuft-shaped Corals, free, to a great extent, at the surface, and others are only isolated at the calicular surface, and form masses, and a third group are completely fixed and confluent, forming very diverse-shaped Corals.

Another sub-family is that of the Stylinaceæ, which was largely represented in the Mesozoic and

* *Caryophylliaceæ.* † *Cœnocyathus.*

Tertiary ages, and which is almost extinct. They grow regularly and without the fission; the buds become polygonal as they grow upwards in company, and they mostly have a styliform columella. Some of these were great reef-builders of old, and the buds and parents were all united as a cellular mass, by exothecal structures and by epitheca. One exceptional genus still flourishes, and in this the buds, or corallites, are free above, and all united below by a dense growth, like an exotheca, and which is termed peritheca. It is the common Galaxea.

The group Astræinæ have spines and serrations on the free edges of the septa. It is a very unsatisfactory division, but it is remarkable that the sub-families of the Eusmilinæ are represented in the Astræinæ, the difference being only in the septal structure. They are usually massive compound Corals, and dwellers in shallow water and reefs. But there are some which are simple and solitary, and they belong to the sub-family Lithophylliaceæ, which, however, contains compound forms also. This sub-family has some of its Corals in tufts and others in lines or series more or less confluent, and these last are subject to growth by fissiparity, the calices being often very long and curved, or meandriform. The genera Montlivaltia and Antillia belong to the simple kinds, and the first has fossil and the second both fossil and recent forms. The tufted Montlivaltia group are represented by the Mussas of the warm seas of the great oceans, and by the extinct genera Thecosmilia, Rhabdophyllia, and many others. Many massive Corals, with many small calices arranged in long, wavy, trough-like series, exist amongst the meandriform group, and are classified under the genera Symphyllia, Mycetophyllia, Isophyllia; and in some the septal edges are extremely spinulose. The very solid-looking, wavy-caliced Mæandrinæ belong to this group, and the common Corals so frequently sold at sea-side places, with slightly elongated deep calices, belonging to the genera Leptoria, from the Red Sea and Pacific and Indian Oceans. The Brain Stone Coral (*Diploria cerebriformis*) is one of these. Numerous fossil species of still existing or extinct genera are recorded.



DIPLORIA CEREBRIFORMIS.

Another group of these ragged-topped septate Corals increase by the division of their calices, but grow up in a solid mass, the division being restricted, and all the resulting individuals being united together by exotheca. Some of these have the costæ of one corallite uniting with those of their neighbours, and pali may exist. Some Atlantic, Red Sea, and Pacific Ocean shallow water Corals of this group are the Faviæ, and there are extinct species also. The lobed Goniastræa belongs to this series.

The sub-family Astræaceæ are Corals with spiny or serrate septal edges which reproduce by ova; but the individual is enlarged by a process of budding, which may take place from the outside of the Coral, and from just outside the margin and from within the calice. The buds grow, and are united by a dense exotheca, and the solidity of the whole is often increased by the costæ of the corallites, or separate parts of the mass, being united. The calices are separate in some genera, as in Heliastræa, and in such as bud outside the calice. Others, which bud within the calices or at the margin of them, have polygonal, elongate, and even very confused calices, and they may be joined by the

costæ passing from one calice to another, or by special structures. The genera Astræa and Prionastræa amongst the recent Corals, and Isastræa and Thamnastræa belonging to the extinct fauna, are familiar examples.

The Cladocoraceæ are a sub-family with dendroid-shaped Corals, and some of the genera are extinct. *Cladocora cæspitosa* is a well-known species of the Mediterranean, and other species inhabit the West Indian Seas and Madeira. Some of the spined septate Corals bud in a remarkable manner from a kind of creeping root, or stolon, and the corallites thus arising may or may not be covered with epitheca. These are the sub-family Astrangiaceæ, and the genera Cylicia, Cryptangia, and Astrangia are types, some species being extinct. Finally, two little groups, the Echinoporæ and Merulinæ, are the last of the series, and lead, by their structural peculiarities, to the next family.

DENDROPHYLLIA RAMEA.

FAMILY FUNGIDÆ.

This family is characterised by the flat growth of the corallum, and especially by the occurrence, in the interseptal spaces, of stout, straight dissepiments, simply stretching across from septum to septum, like little beams. These are Synapticulæ. There are two sub-families. In the first, the Funginæ, the under part of the wall or base is more or less porous and spinulate. The common large simple Coral (*Fungia patella*), so like a flat mushroom, and which is found very generally on the shores of the Eastern seas, is the type. Another, elongate in shape, has been compared to the Sea-slug, and is a large Coral.* Several genera are extinct, and Micrabacia of the Chalk is an example. In the sub-family Lophoserinæ, the wall is entire and not spinose, and it contains some twenty genera. Some have the species simple and cup-shaped, or button-shaped; others are compound. Agaricia is a typical genus. Moseley obtained a beautiful Coral (*Bathyactis symmetrica*) from a wider range than any other known Coral—from thirty fathoms to three miles of depth, and in all the oceans. There are instances amongst the Fungidæ, as well as in the Aporosa, where the buds become disconnected from the parent, and form other and independent Corals. The family was represented in the early Secondary formations, and has persisted.

GROUP MADREPORARIA PERFORATA OR POROSA.

The group of the Perforate Corals, whose hard texture is reticulate and open, is subdivided into two families. In one, the Madreporidæ, the wall is porous, but the septa are more or less lamellar and entire; and in the other, the Poritidæ, the wall and septa are both reticulate and porous.

An important sub-family of the Madreporidæ is that of the Eupsamminæ, in which the smaller and younger septa curve towards the older ones close by, so that a very elegant pattern is formed. The Dendrophyllia dredged up in the Mediterranean and off Madeira, and which has a curious scent, belongs to this sub-family, and the most beautiful Corals known, the Stephanophylliæ, also. These are found living at considerable depths at the present time, and there were exquisitely beautiful species in the Secondary and Tertiary ages. A very remarkable form, called *Leptopenus discus*, a

* *Herpetolitha limax.*

very elaborate piece of coral lace, flat and wonderfully fragile, was got up from 2,600 fathoms in the Indian Ocean, and described by Moseley as one of these. The branching Madrepores belong to a second sub-family, and they are the most vigorous of the reef-builders, living on the outer edge of the reef, and attaining great bulk. Some live in quieter water.

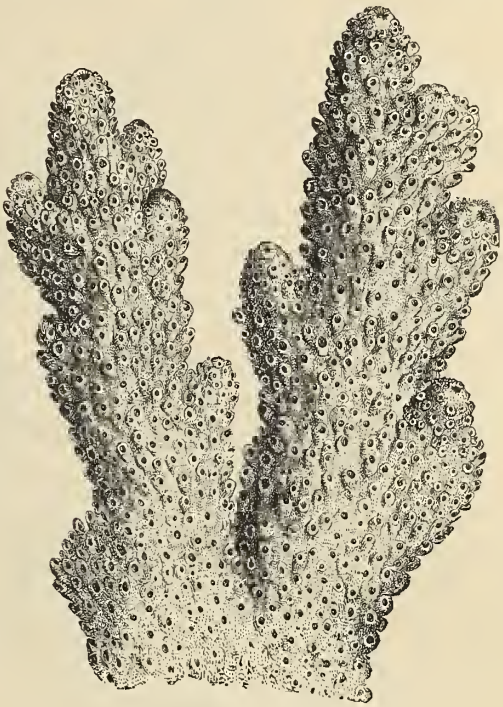
The second family, the Poritidæ, is composed of two sub-families: the Poritinæ, with little or no tissue between the corallites, which are tolerably close together, as in Goniopora; and the Montiporinæ, which have a spongy intermediate tissue. Nearly all the species are reef-builders, and all are shallow water dwellers. Porose Corals existed in the Palæozoic age.

Other great divisions of the Madreporaria are the Tabulata, Tubulosa, and Rugosa.

It has been noticed, in treating of the Hydrozoa (page 292), that some of the Tabulata belong to that class. There are some of this great group of the Corals which cannot yet be classified satisfactorily. Some certainly belong to the Alcyonaria, a group which will be considered in a future page, and one genus, Pocillopora, which has tabulæ and twelve tentacles, with very rudimentary septa, probably should be referred to the Aporose division of the Madreporaria. Others of the old group Tabulata may be Bryozoa.

The Tubulosa contain two genera, which are extinct, namely, Aulopora and Pyrgia, but their classificatory position is very undecided, and probably they were Alcyonarians.

Lastly, the Rugosa, a grand group in the Palæozoic age, in which they were reef-builders, has some modern representatives in the small Guynia and Duncania of the floors of the Mediterranean and Atlantic Ocean.



MADREPORA PLANTAGINEA.

SUB-ORDER ANTIPATHARIA, OR SCLEROBASIC ZOANTHARIA.

These are mostly slender and branched animals, fixed on to substances at considerable depths, and very plant or bush-like in appearance. The inside of their stem is solid, and is composed of hard concentric layers, with a central space, and may be corneous or calcareous. It is covered with soft tissue, which is continuous with the polypes which form the outer living part. The whole is, as it were, a colony, and there is great symmetry in its size, colour, and arrangement. The polypes resemble small Anemones; no hard parts are within their derm, and their base rests on and forms the solid stem or axis. They have six to twenty-four simple tentacles. In the genus Cirripathes, the shape of the stem is that of a stick, and it is covered with little sharp spinules; and in one from the Fijis the stem is very flexuous, and is often spirally curved, the polypes are green, and the tentacles brown, and the surface is ciliated. The genus Antipathes has a black, hard stem, like ebony, and it is more or less echinulate, and ends in small barbules. The species differ in the kind and amount of branching, and whether they are spiny or not. They live on the floor, at moderate depths, of the Atlantic, Pacific, West Indian, and Indian Oceans, and the Mediterranean Sea. Six tentacles are present, and two mesenteries. In the genus Gerardia the hard stem is branched and rough like shagreen, and the soft tissue is dense, and contains silicious spicules; but they appear to belong to other animals, and are accidental. There are twenty-four tentacles, and as many mesenteries. The species are from the Mediterranean and West Indies. A vitreous or semi-hyaline-looking stem, more or less fan-shaped in its branching, characterises the genus Hyalopathes, of the Indian Ocean. In all these genera the hard stem is the product of the base, or lower part of the outer skin of the soft polype-bearing textures.

SUB-ORDER ACTINARIA, OR MALACODERMIC ZOANTHARIA.

This sub-order has its members without any hard calcareous deposit in the mesoderm and base, and the soft parts closely resemble those of the Stony Corals. In some instances there are calcareous spicula in the tissues. There are two families: the Actinidæ, with the tentacles in several alternating cycles, each corresponding to a special perigastric loculus; and the Cerianthidæ, whose tentacles are in two concentric circles, so that an inner and an outer tentacle arises from the same perigastric loculus, and their internal cavities are continuous. The mesenteries do not descend to the bottom of the visceral cavity, and the base of the animal has not a fleshy sucker, but the lower part is more or less slender, and is placed in the mud or sand.

ANTIPATHES ARBOREA.

In the genus Cerianthus, of this last family, the base is perforated by a channel, opening externally in a pore, and this very exceptional structure in the Actinozoa is for the purpose of getting rid of undigested matters. A kind of flexible sheath is found around the species, and is produced by an aggregation of nematocysts cast forth by the skin. They are principally inhabitants of the Mediterranean, but a species was found at 2,780 fathoms in the Atlantic, and was described by Moseley. It was dwarfed, its anatomy was exceptional, and it was contained in a tube made up of the threads of its nematocysts.

The great family of the Actinidæ is subdivided into two groups. In one the bodies have a disc at their base or foot, and are more or less separate; and in the other there are sclerites or hard spicula in the tissues, which give a coriaceous texture to the mass.

VERTICAL SECTION OF SEA ANEMONE.

a, mouth; *b*, cavity of stomach; *c*, body cavity; *d*, intermesenteric chamber; *e*, generative filaments; *f*, mesentery; *g*, tentacle.

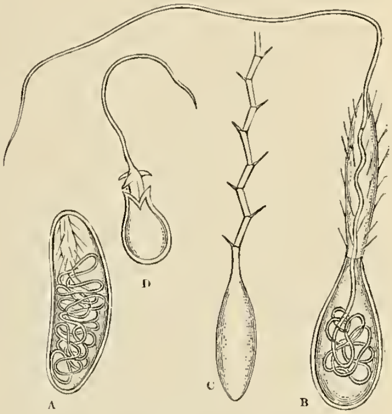
Amongst the first division are the Minyadinæ, which do not fix themselves by their base or foot, but, by contracting it, form a more or less hollow space. Air is taken into this cavity, and the animal floats freely, with its tentacles and mouth downwards. The blue Minyas* of the Cape of Good Hope is melon-shaped, and flattened above and below; it is blue, with white projections on it. Moseley described a floating form, with a cylindrical body and flattened base, which was obtained during the *Challenger* Expedition off the north-east of Australia, and one from 700 fathoms. The next division is that of the Actininæ, the great majority of which have an adherent base, which they can fix and unfix, and they have one kind of simple tentacles. At least twenty-four genera are included in this division, and there are a vast number of

* *Minyas cœrulea.*

SEA ANEMONES.

1, Cereus (Bunodes) coriaceus = crassicornis; 2, Adamsia parasitica; 3, Actinia (Metridium) dianthus; 4, Sagartia viduata; 5, Sagartia rosea; 6, Cereus gemmaceus; 7, Anemonia cereus.

species. The well-known genus Anemonia has an adherent base, and is without any pores in the sides of the body, which are smooth. Its tentacles, very numerous, are not retractile, but long. The margin of the tentaculiferous disc has no coloured bodies, and the tentacles are conical. It was called Anthea by Johnston. *Anemonia cereus* has from 100 to 200 tentacles longer than the body, and they are green, or olive and brown tipped with rose, with a brown disc, with green radii. It inhabits the rocks of the English Channel. *Anemonia tuedia*, with short tentacles, inhabits the Scottish coasts. Other genera have coloured bodies on the outside of the disc.



THREAD-CELLS OF SEA ANEMONE.
A, quiescent; B, C, D, ruptured.

The genus Actinia has tentacles that can be retracted, and it has the chromatophores, or coloured bodies. *Actinia mesembryanthemum* is the common Red Sea Anemone of the south of England, and it is a hardy thing, liking to get out of the water now and then on to the rocks, and to remain there closed, and then to re-enter by crawling with its disc. It is very voracious, and grows to a moderate size, and lives years in confinement.

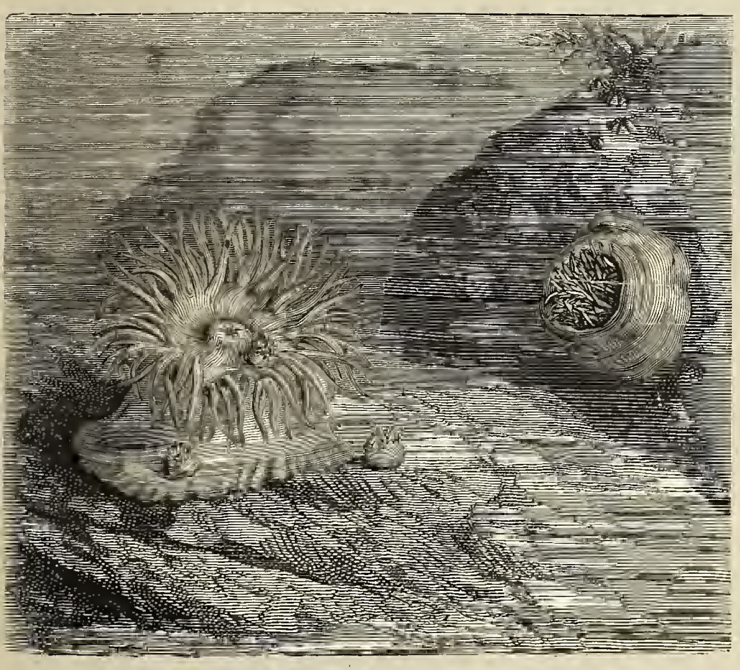
Actinia anguicoma and *A. pallida* are also English species.

The genus is found in all the northern seas, the Mediterranean, the Atlantic, and on the Pacific coasts.

Moseley has described Actiniæ from 1,075 to 1,350 fathoms' depth in the Atlantic, clinging on to the stems of a Mopsea.

The genus Paractis of the South Seas and Atlantic has no chromatophores.

The pretty Dianthus Anemone belongs to the genus Actinia, and has its disc lobed. An allied genus is that of Discosoma, and it contains a huge form, which measures two feet across, and which lies flat like a carpet on the mud of the Red Sea. This genus is Mediterranean and Pacific in its distribution.* The genus Corynactis has the tentacles swollen and sub-spherical at their ends, and Melactis has a protractile mouth and knobbed tentacles. An epidermic envelope surrounds the red *Capnea sanguinea*, and a Dysactis from Guernsey † has a long body, narrow below, with two crowns of tentacles very distinct, but contiguous at their origin. The largest are filiform and white, and the others are small and orange in colour.


ACTINIA MESEMBRYANTHEMUM.

Several genera have wart-like tubercles on the sides of the body, which secrete a sticky substance, and the base, or foot, is very well developed.

The Crassicorn ‡ Anemone of the south coasts of England belongs to the genus Cereus (Bunodes, Gosse), and is well known for its beautiful colours, green, grey, and red, its numerous pointed tentacles, and its voracity. Unfortunately it does not live well in aquaria. It has neither chromatophores around the disc

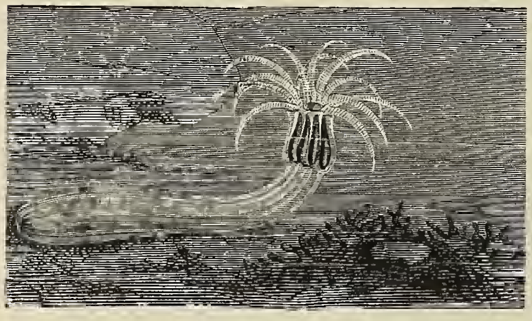
* The deep sea genus Corallimorphus of Moseley (2,028 fathoms) belongs here. † *Dysactis biserialis.*
‡ *Cereus crassicornis.*

nor pores on the outside. A small green species, banded with yellow, is found on the British coasts, and its tentacles are banded with white and green. The warts are arranged in vertical series.* The Gem Anemone † of our coasts has small warts in close longitudinal series, and the tentacles, which are slender, are ringed with white and green tints. The Daisy Anemone‡ can elongate its body considerably, and has a delicate integument of a pale grey yellow, and the warts are restricted to close to the upper part. The disc can alter its shape considerably in a wave-like manner, and the tentacles are very numerous, delicate, smallest externally, and they are ringed with grey and white tints. Another species, *Cereus venusta* (*Actinia venusta*, Gosse), has a brownish orange-coloured body, very numerous tentacles, and it emits an abundance of filaments with nematocysts, when it is irritated.

Several other species are found in the English Channel, and the genus frequents nearly all the shores of the great oceans.

The genus Phymactis differs from Cereus in having chromatophores around the disc, and the species are from Peru, the Cape, St. Helena, Brazil, and Australia. Cystiactis has large prominent tubercles on the body, and has a South American distribution. An Anemone which usually selects an empty whelk-shell to fix its base upon, has a leathery consistence of body and short tentacles; the tints are greyish-yellow, banded with red-brown, and the tentacles are banded with the same colours. It has pores situated near the disc. It is *Adamsia effœta*. Another species inhabits the surface of shells in which the Soldier Crabs reside, and its very flexible body has the disc bordered with a rosy orange tint.§

All the remaining genera of Actininæ have a very small base and an elongate body.



EDWARDSIA CALLIMORPHA.

The species of Iluanthos, known in the Scottish and English seas, differ: in the one the body is elongated and pointed at the base, and the filiform green tentacles are in one row;‖ and in the other the body is squat, with a small base, and the tentacles are thick. ¶ These Anemones are deeply fixed in sand and mud. The Edwardsias have the body attenuated at the base, but there is a dense dermal structure, more or less opaque, into which the animal can withdraw its two ends. In the genus Peachia the body is long, and there is a central orifice in the slender base. The tentacles are in one row, and the mouth has a papilliferous and protractile lip. *Peachia hastata* lives in the sand, with the calice just visible, in the English Channel. It appears that the young form of one of the Edwardsiæ, has eight tentacles, and only two mesenteries.

The sub-family Phyllactinæ contains Anemones which have some of the tentacles branching, or compound in their structure. In the genus Phyllactis the simple tentacles form an inner row, and the compound leathery ones, an outer crown. The Thalassianthinæ have all the tentacles ramose or papillate. Finally, the Zoanthinæ are aggregated polypes, which increase by budding at the base, and they have a coriaceous false skin, in which the secretions are mixed with concretions of sand and shells.

* *Cereus chrysoplenium* (Johnston). † *Cereus* (Bunodes) *gemmaceus* (Gosse). ‡ *Cereus bellis.*

§ *Adamsia palliata.*

Some of the Actininæ, such as the generas Actinia and Cereus, have the ova and spermatozoa developed in the same animal, and other genera are unisexual. The ova undergo their early changes in the parent, and a ciliated planula is set free. An oval depression appears at one end of it, which becomes the mouth and gastric sac. There is a tuft of cilia at the base end, and the planula swims with it forwards. Then the mouth elongates in one direction, and two mesenteries are formed out of the mesoderm, so that the planula is bilaterally symmetrical, and has an internal cylindrical canal communicating with a bilobed perigastric cavity, which separates it from the body-wall. Another pair of mesenteries make their appearance in one of the spaces between the two mesenteries, and thus four mesenteries and four inter-mesenteric spaces are formed. Then a pair of mesenteries appear in the other space, so that altogether there are six. Then two more are added, and there are eight mesenteries and chambers. Subsequently a fifth and sixth pair are developed, and twelve mesenteries result. Seven of them have come from the division of the first primary, and five from the second primary chambers. These researches by Lacaze-Duthiers connect these presumedly radiate animals with those having a bilateral symmetry, and group together the Anthozoa with four, six, and eight tentacles or their multiples.

‖ *Iluanthos scoticus.* ¶ *Iluanthos Mitchelli.*

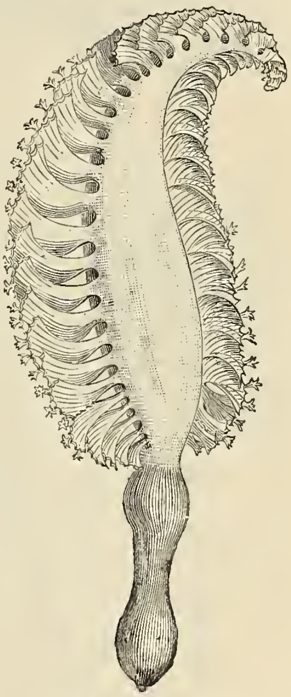
THE ORDER ALCYONARIA.

The numerous members of this order are well distinguished by having eight tentacles, or tentacles in multiples of four, which are very regularly pinnate. They form a single row, or cycle, and are enlarged at their base, and each communicates with one of the eight perivisceral spaces around the stomach. Certain boat-shaped spicules are found in groups, at the base of the tentacles and in the derm, and are often coloured. The mouth varies in its shape, but has not a bilobate form. The stomach terminates, internally, in an orifice surrounded by a sphincter (pylorus). Eight mesenteries project from its outer surface into the perivisceral cavity, and reach the walls of the body to which they are fixed. Each inter-mesenteric space is continuous with a hollow tentacle above, and below it communicates with the visceral chamber near the pylorus. The visceral cavity beyond the pylorus is variable in its size ; in the genus Corallium and in the Gorgonias it is short and rounded below, but in Alcyonium it is long, and narrow in shape. The body is very soft and retractile at the upper part of this portion of the cavity, but at the lower part the dermal tissues contain sclerites and spicules. A calcareous stem often results, which may branch, and become thick and concentric in its structure, or spicules may simply strengthen the integuments, and in the first family coral-like structure exists.

The family HELIOPORIDÆ contains the so-called Blue Coral (*Heliopora cærulea*), which is found on many Pacific coral reefs. The Heliopora has a massive, hard, calcareous skeletal structure, with pores on its surface leading down to tubules, which are crossed by tabulæ or horizontal floors. The soft parts cover the hard, and dip down within the pores and to the level of the uppermost horizontal tabulæ. The pores have little projections, like imperfect coral septa, and there may be from twelve to sixteen. But at a slight depth in the calice Moseley, to whom we owe the anatomy and zoology of the group, says the projections become eight in number, and in the living animal a mesentery passes to each internal projection. The soft tissues of this hard cellular mass are composed of an ectoderm, mesoderm, and endoderm. The first is superficial, and is also prolonged to form a lining to the stomach. The mesoderm has connective tissue, layers of cells, and masses of fibrillar tissue, and the carbonate of lime of the skeleton is produced in the first. The endoderm forms layers lining the centre of the tubes of the hard parts, the calicles, and the interseptal spaces. There are deep superficial canals on the top of the hard skeleton, communicating with the calices of the pores, and they are lined with the three dermal elements. The polype with its tentacles has not yet been seen expanded, but Moseley has drawn the unexpanded condition, and has shown that retractor muscles exist, which withdraw it into the pore, down to the upper tabula. Very small nematocysts occur in the ectoderm. There are eight lobes in the unexpanded polype, and eight tentacles exist, and there are evidences of short stout tubercles on them. Moseley found ova in about three polypes out of a hundred, but no spermatozoa ; so in all probability these tabulate Alcyonaria are unisexual.* The fossil genus Heliolites, of the Palæozoic age, is a close ally of the Heliopora, which has itself been found fossil in Secondary rocks.†

THE FAMILY PENNATULIDÆ.—THE SEA-PENS.

These are free-swimming, more or less pen-shaped Alcyonaria, and some live with their slender pointed root in the sand and mud, but they are not fixed. Their surface is soft, and may have three kinds of polypes, or zooids, upon it, continuous by their bases. They are connected with the central stem, or axis, which is fistulose, and made up of horny and calcareous matter, traversed by



PENNATULA (PTEROEIDES) SPINOSA.

* H. N. Moseley, F.R.S. : Report on Corals, *Challenger* Expedition.

† Allusion has been made to the Tabulata as a group already ; and Moseley's researches almost necessitate the placing of the Favositidæ of Milne-Edwards and Jules Haime amongst the Alcyonaria, so that the group is very old, and was Palæozoic. Some forms, however, are Bryozoa.

soft tissue in bands. The lower part of the axis is not covered with zooids, and the upper part may have its surface with zooids on one or both sides in simple series, in spiral series, or in groups on one or both sides. When the upper part of the axis is branched, the pen-shape may be single or double, and crowds of zooids with spinules are arranged on one edge. The ectoderm usually contains calcareous spiculæ. The Sea-pens live in shallow water, and also at great depths, and their distribution in the ocean is very wide. The sub-family Pennatulæ contains the genus Pennatula, in which the zooids are on the ventral and lateral sides of the stem, there being always a bilateral arrangement of them on the long cylindrical pinnate stem also. Many are very phosphorescent, and most live in shallow water, some going down to three hundred fathoms. Their colours are often brilliant red, and the specimens may be a foot in length. The stalk, or lower part of the axis, swells out, and then terminates in a slender end, or it may be short and cylindrical. The spicules have the tint of the whole. The zooids are on the tufts, and not on the stem, in the genus Pteroeides. In the genus Virgularia the root is stout and bent, the axis very long and often curved, and the zooids are on either side, on the short pinnules. Calcareous needles are scanty in the stalk and tentacles. In the genus Scytalium, the zooids, placed side by side, resemble the half of a young leaf, and the pinnæ are thick, whilst in Pavonaria, the zooids are on the thick edge of the four-sided stem. A magnificent form, called Anthoptilum Thomsoni, after the late director of the *Challenger* Expedition, has a round and long axis, and the zooids are in many short rows on it. It was found at six hundred fathoms' depth, south of Buenos Ayres, and another species at a depth of 1,200 fathoms. The family Umbellulidæ have a long sterile axis, and from about twenty to fifty zooids are grouped together at the upper end, in a more or less umbrella form. Some species were found at a depth of from 1,200 to 2,125 fathoms.

UMBELLULARIA GROENLANDICA.

The family Renillidæ have a kidney-shaped body, without a solid axis, and the zooids are on one side of their single pinnule. The Veretillidæ have an elongate axis, which has retractile zooids over the entire surface, and its lower part is bulbous, naked, or soft. It is divided longitudinally by two intersecting membranes, with a calcareous axis in the lower part of the stem, or it may be simple and fleshy.

THE FAMILY OF THE GORGONIDÆ.

There are vast numbers of branching, slender-stemmed, compound Alcyonaria living fixed on the floor of the sea at different depths. They have a cellular soft part, in which are the zooids, or polypes, with eight pinnate tentacles, and this surrounds, in the manner of a bark, a more or less horny or calcareous stem, which is fixed at its base. The soft tissue is furnished with sclerites or spiculæ, and a canal system is on the outside of the stem, or sclerobasic axis. It appears to have to do with the general nutrition and symmetrical growth of the whole, and probably it communicates with the visceral cavities of the polypes. The visceral cavities of the polypes are short, and rest, as it were, on the outside of the central stem. There are two great divisions of this family; in one the axis is flexible, horny, and only partly calcareous, and in the other it is completely calcareous. The first division relates to the sub-families Gorgoniæ and Isidinæ, and the last to the sub-family Corallinæ.

The beautiful Red Coral,* which is used so much as an ornament, is the cleaned hard stem of an Alcyonarian, which lives fixed to substances at considerable depths in the Mediterranean and some parts of the Atlantic and Pacific. The red stem has delicate striations on it, and a section shows a concentric arrangement of calcareous matter, tinted various shades of red. The animal forms this by deposition of the calcareous grains in a connective tissue, and covers the whole with a somewhat dense soft part. In this there are canals, or water-systems, running over the hard stem, conforming to its markings, and communicating with smaller canals. The soft parts, moreover, above the canals are formed into polypes, or zooids, which are contractile and very extensible. They have a thick base, which narrows upwards to a point, whence a swelling extends, capped by eight feathery tentacles. Muscles exist to retract the zooids, but nerves have not yet been distinguished. A mass of spicules environs the hard stem, and is gradually connected to form the outer layer. The zooids are unisexual or bisexual on the same stem, and the ova form a planula covered with cilia, like a little white worm. It swims freely, and settles down after escaping from the mouth of the parent, remaining permanently adherent to some substance on the floor of the sea. The changes then proceed which lead to the formation of a mouth, stomach, and perigastric cavity; and the calcareous matter gradually deposited by connective tissue, and forming the stem and the spicules, is derived from the products of digestion. As in the case of the Stony Madreporaria, the carbonate of lime of the skeleton is not got from sea-water, but from the shells of the minute animals which constitute the food. The deposition of the carbonate of lime thus obtained in certain tissues is analogous to the formation of bones in the Vertebrata and shells in the Mollusca. There is a very important coral fishery off the coast of Algeria, near Calle, and also off the east coast of Spain, and the article is systematically obtained by a rude dredging or breaking-off and bringing-up apparatus. The coral fisheries of the coasts of Italy and Sicily begin about the middle of February and continue into October. Pale coral is the most prized now. Off Torre del Greco a large quantity of coral is found every year, and from 400 to 600 boats of from six to ten tons are employed. The cost per boat is from £500 to £600, and the Coral, when good, is worth from £80 to £200 an ounce. Dana describes a branching, more or less fan-shaped Coral, of a pale colour within and brilliantly red outside. It is also found off the Sandwich Islands. These species belong to a sub-family—the Corallinæ—and it was represented in the age of the Chalk at Faxoe, and in the Miocene of Turin and Sind.

CORALLIUM RUBRUM.

CORALLIUM SPICULE.

Other dwellers on the floor of the sea, possessing branched stems, have the calcareous part of it not continuous, but in more or less cylindrical or flat pieces, separated by horny tissue. They are the sub-family Isidinæ; and the genus Isis has the polypes on the calcareous pieces which are striated. The branches arise from the calcareous parts. *Isis hippuris* is from Amboina, and *Isis polyantha* from the American seas, whilst *Isis coralloides* is from the seas of India. This widely-distributed genus has naturally fossil forms, and they have been found in the Cretaceous and Miocene strata of Europe, and in the Miocene of Sind and Australia.

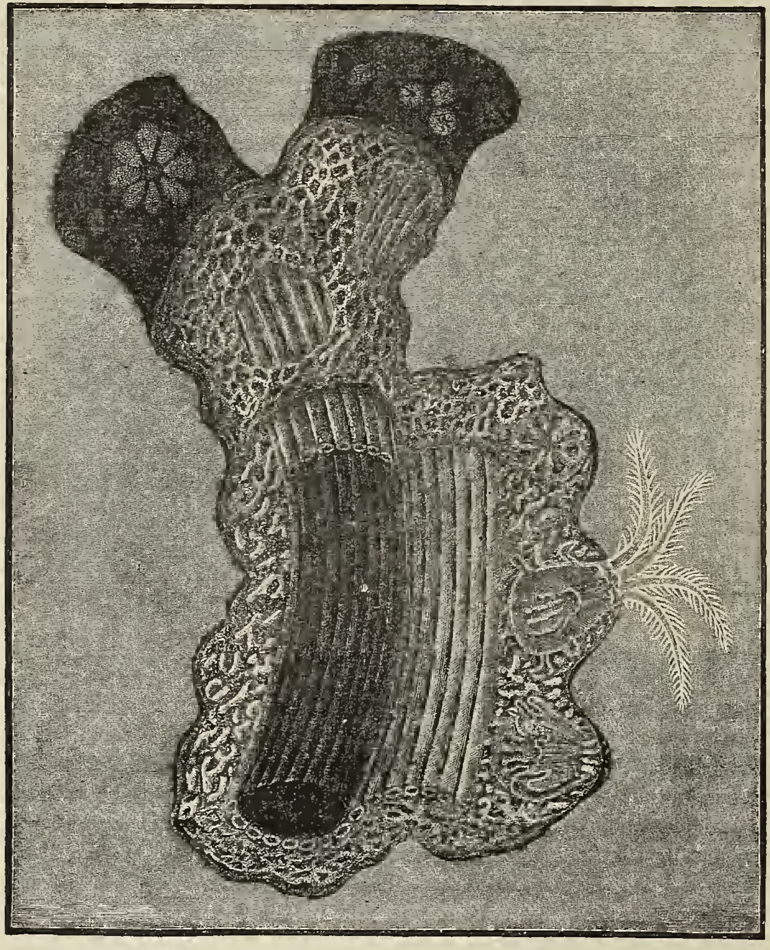
In the genus Mopsea, a dweller on the deep-sea floor, the branching takes place from the inter-calcareous or horny part, and there is a fossil Eocene form of it.

In the genus Melithæa the outer calcareous parts are porous and corky in appearance.

The sub-family Gorgoninæ has a flexible continuous stem which resembles horn more than chitine. The environing soft parts are well developed, and the polypes may be sunken in it or may project as little warts. There are spicules of carbonate of lime in the soft parts, and sometimes there is some of that mineral in the stem. The stem, marked with grooves on the outside, is formed

* *Corallium rubrum.*

of concentric layers, and they are deposited in the tissues of the deepest portion of the soft parts, one over the other. The nodular spicules are very characteristic, and in some genera they crowd the softer tissues. Some are knobbed at both ends and along their short stem, and the knobs are like cauliflowers; others, with four or five crowns of tubercles, are fusiform; many are club-shaped, with longitudinal crests, or are spiny, and many are scale-shaped and spinose.

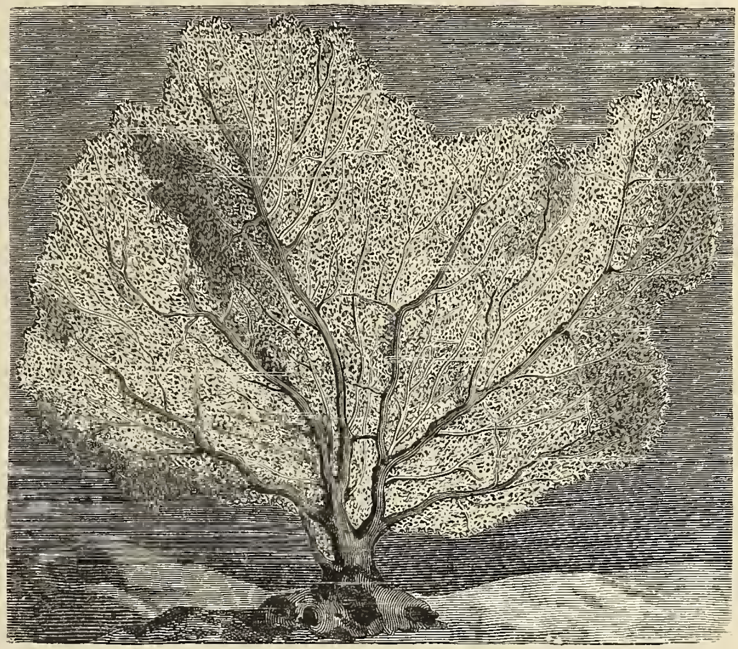


ENLARGED SECTION OF STEM OF CORALLIUM RUBRUM (THE RED CORAL).

The great number of genera of this sub-family may be arranged around certain well-marked ones or types. The genus Primnoa has a dendroid stem and long warty or pedunculated knob-like appendages. Each of these contains a polype which is crowded with imbricated scale-shaped spicules. These are movable on their bases. The axis is cylindrical and delicate, and contains some carbonate of lime. They are found in the Atlantic, the Mediterranean, Red Sea, and Pacific Ocean. The genus Gorgonia is a type, and about ten others are grouped with it. The stem contains no carbonate of lime, and is corneous. *Gorgonia verrucosa*, of the Mediterranean and English Channel, has a bush-shaped form, or is like an espalier. It branches much, but so as to develop a fan-shaped outline. Some are half an inch and others one-eighth of an inch in diameter. The polypes are on knob-shaped projections, and have a circular margin.

The nearest ally to Gorgonia is the genus Muricea, and it has a softer stem, and the polypes are, as it were, bi-lobed. The Western seas of America appear to be its home. Other genera such as Plexaura, have the polypes sunken in the common soft tissue, which is thick and semi-solid. Its species come from the Antilles, the Canaries, and the Pacific. Leptogorgia, on the contrary, has a thin, almost membraniform, soft tissue, and the margins of the polypes do not project, and there are no knobs or warts. A flat stem, branching in twos, and forming a plume shape, is characteristic of the genus Lophogorgia; and when the polypes, instead of being placed all around the stem and branches, are restricted to longitudinal lines on either side of a median groove, the forms belong to the genus Pterogorgia. Other genera have a foliaceous-looking stem, some are in straight sword-shaped masses, as Xiphigorgia, and the rest have the branches uniting, so as to form a leafy shape. In Rhipidogorgia the fan shape is very decided, and the soft parts have little warty polypes close to the hard tissue. This genus has many species in the Australian, Pacific, and Atlantic seas. In fact, the world-wide distribution of nearly all these genera is very remarkable. Another type

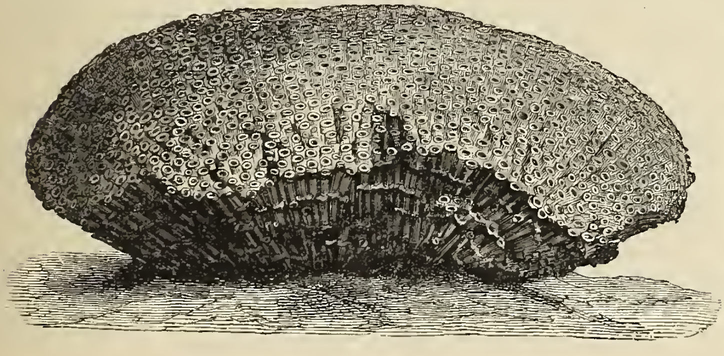
has a large quantity of carbonate of lime in its stem, and it is interesting to note the repetition of external form, in this division, of that noticed amongst the corneous-stemmed forms. It is the genus Gorgonella, and it corresponds to the Leptogorgias in the last division, but the axis is very calcareous, and Verucella has the configuration of the Gorgoniæ. One genus, Juncella, has a simple, non-branching, straight stem, like a stick, and the polypes project slightly. It has been found in the Mediterranean, off Bahia, and on the east coast of Africa. The last group is that of the Briaraceæ, in which the axis, or stem, is no longer dense, solid, and concentric, but may be hollow or a mere mass of spicules. Briareum is the typical genus, and Paragorgia is its most important ally.



THE SEA FAN (*Gorgonia flabellum*).

THE FAMILY ALCYONIDÆ.

With the exception of one genus, this great family is characterised by the absence of anything like a continuous skeleton or supporting dense hard structure. In no case is there an axis, as in the Red Coral and Gorgonias, but there is much soft structure, in which isolated calcareous sclerites or spicules are placed, sufficient to detract from a perfect contractility and softness. Hence some are leathery or fleshy. The polypes are fashioned after the Alcyonarian type, have eight pinnate tentacles, and their visceral cavity has membranes in it supporting the reproductive elements. The soft tissues, or cœnosarc, contain the polypes, whose centres communicate with a common series of minute canals. Many forms increase by budding, some from the base and others from the sides, and thus two sub-families, the Cornularinæ and the Alcyoninæ, can be established. There are some forms, however, which produce a wall of calcareous spicules and a kind of corallum, and thus a third sub-family, the Tubiporinæ, is formed. This is a very exceptional form, and the rest are fixed by their fleshy bases. Where the polypes are in considerable numbers and surrounded by a cœnosarc, they extend deeply, and as they are produced by budding they may have their visceral cavities elongate and either in the direction of the lower sides or of the whole mass. Some are very retractile.



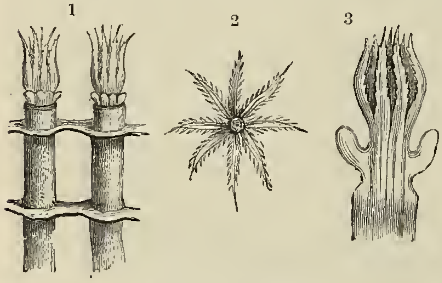
TUBIPORA MUSICA (THE ORGAN-PIPE CORAL).

The Organ-pipe Coral * forms very considerable masses of a deep red colour, and is found in the Red Sea and the Pacific. Its appearance is very familiar to visitors to museums, and it is made up, in the dry and the dead state, of a multitude of small cylindrical tubes placed in rows one over the

* *Tubipora musica.*

other, and separated by a kind of semi-tubular and cellular tissue, which forms layers of considerable extent. Usually the number of tubes is small at the base of a mass, and it increases at each layer of the cellular tissue, so that it is very great at the surface of a large piece. Each tube is made up of a great number of sclerites, nearly united together, so that their original shape cannot be made out, and it is hollow within, and more or less cylindrical. But there are funnel-shaped projections inside, and also incomplete horizontal tabulæ. There are no septa. The tubes are separate, slightly porose, and the new ones spring from the horizontal layers, whose cavities communicate with the larger tubes. The polype fills the upper part of the tube, and its outer derm passes over the edge, or rather is continuous with it, and the sclerites are developed in its midst. There are eight tentacles, with from fifteen to seventeen pinnæ on either side of each, and there are spicules within. The mouth has a slightly raised lip. When the polype is alarmed, the tentacles close, and then the whole is withdrawn into the tube. The lower part of the tube, above the uppermost tabula, is occupied by the gastric cavity, separated above from the stomach by a delicate tissue. The ovaries are in the lower cavity, and the mesenteries, eight in number, are like thin slender cords.

The genus Tubipora forms a sub-family of the Alcyonidæ, and there are several species of it. Probably it is of great antiquity, for there are things like it in the Devonian rocks.



TUBIPORA MUSICA.

1. Tubes magnified and containing polype. 2. Tentacles of *Tubipora* polype. 3. Polype magnified.

The Alcyoninæ are fleshy and soft, and increase by ova, and also in mass by a process of budding from the sides of the polypes. The buds are enclosed in a very strongly-developed cœnosarc, and the mass may be simple, lobed, or branched. There are two divisions of the sub-family. In the armed or spiculate one, the tissue of the body is thin and soft deeply, but the outer derm is almost consolidated or very leathery, on account of the number of large boat-shaped spiculæ. These resemble those commonly found in the Alcyonaria at the base of the tentacles, but which are small in that position. The extremities of the spicules project at the surface, and give an echinulate appearance to the individual. In the genus Nephthya the derm is a leathery skin, bristling with spicules, and it forms branching lobes ending in projecting tubercles in which are the polypes. The only known species is from the Red Sea. In the genus Spoggodes the animal is membranous and flexible, and the polypes are incompletely retractile within the tissue which contains the spicules. An almost cylindrical tube of leathery skin with spiculiferous walls contains the highly retractile polypes of the genus Paralcyonium of the Algerian seas, and this is the nearest ally to the Tubipores. No less than twelve genera belong to the next division of naked Alcyonians. These have a semi-cartilaginous consistence, and merit the term fleshy, but the density is due to the presence of a multitude of microscopic nodular sclerites. The surface is granular and very spinulose. The genera may be grouped according to the contractility of the polypes; and in the genus Alcyonium, which is lobed-shaped or finger-shaped, the contractility is complete. The polypes retreat within a dense cœnosarc; they increase by budding. One of the species* has a singularly hand-shape, and is called Dead Man's Fingers on the English coasts. The polypes are large, very numerous, and occupy the greater part of the surface, and the colour may be white, or grey, or orange. They are fixed on to stones and shells, and the ugly mass of slimy-looking substance if placed in pure sea-water gradually sends forth its beautiful polypes. The genus Ammothea is a branching form, with spicules on the branches, and it probably should be placed with the other division. Its polypes are semi-retractile.

The polypes of the last genus to be mentioned, Xenia, from the Red Sea and Fijis, are non-retractile, and are on a fasciculate and fleshy stem.

Amongst the genera of the sub-family, the Cornularinæ, are some simple or isolated forms, or they may be united by a kind of prolonged base or stolon, out of which they have been formed by budding.

The simple kinds have a tubular shape, and the polype is retractile, and they belong to the

* *Alcyonium digitatum.*

genus Haimea. Compound kinds may have root-shaped stolons, and the polypes may be tubular. In some of these, the Cornulariæ, for instance, the polypes are completely drawn in, and are retractile, and the stolons fix on to all kinds of substances. There are no spicules, and the bottom of the visceral cavity communicates with the buds by minute canals. They are Mediterranean species. The Clavulariæ resemble these, but contain spicules, and inhabit the shores of Vanikoro. Some species without retractile polypes, but otherwise like the Cornulariæ, are found in the Moluccas, the Bay of Naples, and coast of Norway. They belong to the genus Rhizoxenia. Some wart-shaped polypes, hardly higher than the stolons which bear them, characterise the Sarcodictyons of the Scottish coasts. The colour of the stolon in one species is red, and the polypes are yellow, and in another the tint is yellow-brown.

The next division refers to species which have a membranous basal expansion, and not stolons, and in the genus Anthelia the polypes are very projecting, and when it contracts the tentacles come within the base.

The ancient forms of the Anthozoa have been slightly alluded to in the past pages, and it is necessary to add that the groups Aporosa and Perforata were faintly foreshadowed in the Palæozoic ages, and began to be of importance in the early Secondary times. The Aporosa appear to have been the most numerous. The reefs of the Oolitic age had a great fauna, and the chalk contains relics of a fauna which resembled that of the deep seas of the present time. Many genera of Tertiary corals are now existing, and a few species also. The group Rugosa is a very difficult one to define, and it flourished during the Palæozoic age. In many forms the septa are so close together, and the space between them is so restricted, that it is doubtful whether mesenteries and ovarian apparatus could have existed there. In some there is a groove, or more than one, in the place of a principal septum; and in several genera of compound kind the columella and surrounding septa almost recall the Stylasters. Some of the Rugosa may have been corals having soft parts, something like those now existing, but others were probably Alcyonarians, and not a few must be classified near the Millepores.

CLASSIFICATION.

CLASS.—ANTHOZOA.
- ORDER.—ZOANTHARIA.
  - *Sub-order.*—Madreporaria.
    - *Group.*—Aporosa.
      - *Families.*—Turbinolidæ, Oculinidæ, Astræidæ, Stylinaceæ, Astræinæ, Fungidæ,
        - *Sub-family.*—Stylophorinæ.
    - *Group.*—Perforata.
      - *Families.*—Eupsamminæ, Poritidæ.
    - *Group.*—Rugosa.
  - *Sub-order.*—Antipatharia
  - *Sub-order.*—Actinaria.
    - *Families.*—Actinidæ, Cerianthidæ.
- ORDER.—ALCYONARIA.
  - *Families.*—Helioporidæ, Pennatulidæ, Gorgonidæ, Alcyonidæ.

P. MARTIN DUNCAN.

THE GROUP SPONGIÆ.

The Turkey Bath Sponge as a Type—Its Structure and Embryology—Its Mode of Life—Specific Distinction and Existing Distribution—Sponge-farming—Forms and Colour of Sponges—The Individuality Question—Different Types of Canal System—The Three Primary Layers—The Skeleton—Spicule Forms—Embryological Development—Affinities of the Sponges—Their Classification—General Characters of Existing Families—Their Distribution in Space and Time.

THE Sponges are a numerous, diverse, and yet compact, group of animals, manifesting, amidst a remarkable diversity of minor characters, a fundamental similarity by which they are united closely together, and separated from all the rest of the animal kingdom. In a word, they are Metazoa, or multicellular animals, in which the endodermal layer characteristically consists, partly or wholly, of flagellated collared cells.

A clear idea of the nature of a Sponge will be most readily obtained from a description of a single well-selected example, and none is better suited for the purpose than the common Bath Sponge. The object which is usually denoted by that name is but the skeletal remains of the animal—a delicate elastic network, which so intimately pervades every part of the living organism that, after all the other tissues are removed, it still presents a faithful model of the general form and structure of the whole.

There are several kinds of Bath Sponge, but the one to which we shall restrict our attention is the fine Turkey Sponge (*Euspongia officinalis*), of which there are several well-marked varieties, differing greatly in form. Some are cup-shaped masses, with thick walls, or more or less globular clumps; others flat, somewhat ear-shaped plates; and others, again, encrusting patches from which small tubes grow upwards. The colour of the exterior is usually some tint of brown, varying from yellowish-grey to black; within it is of a lighter shade, varying from greyish-yellow to colourless, but in one variety it is rusty red.

A thin skin covers the whole surface of the Sponge, rising, tent-like, about the projecting ends of the chief fibres of the skeleton. These projecting ends can readily be seen with a lens on an unused skeleton of a Bath Sponge.

In various places, irregularly distributed, the skin is perforated by circular holes known as oscula, which can be opened or closed by the movements of a delicate iris-like membrane which forms their margin. The oscula are the terminal openings of wide tubes which descend into the interior of the Sponge, repeatedly branching like the roots of a tree in their course till they become too small to be followed by the unassisted eye. They are known as the excurrent canals; and the tubular spaces in the skeleton corresponding to them, as well as the general position of the oscules, are clearly visible in the Sponge of domestic use. Besides the oscules, large circular openings, characterised by the absence of the iris-like margin, are sometimes, but by no means always, present. They lead into wide canals which are usually tenanted by some large marine worm (*e.g.*, *Nereis costæ*), which was regarded by Peyssonel as "the essential animal and sole fabricant of the Sponge, all the rest being merely a nidus or excretion!"

On examining the surface of the Sponge with a strong lens, there will be seen over those areas devoid of oscules a number of thread-like ridges descending radiately down the tent-like elevations of the skin, branching as they go, and united laterally by similar but transverse ridges into an irregular network with polygonal meshes. A number of round apertures, called pores, are situated in these meshes, and give them a sieve-like appearance (Fig. 2). The pores lead into a roomy space, the subdermal cavity, which spreads beneath the skin; from it canals descend direct into the interior of the Sponge, and sooner or later become branched; these are known as the incurrent canals (Fig. 1).

Thus the Sponge consists of a fleshy mass, supported by a network of elastic fibres, invested with a skin, and traversed by two sets of canals—excurrent canals, each opening by a single oscule to the exterior, and incurrent canals, which communicate with the exterior by cribriform pore areas. Nearly this much, if we except the distinction of the canals into two kinds, was well known at a very early date, probably from the time of Aristotle, two thousand years ago; but so little does the structure, so far ascertained, resemble that of any other kind of animal, and so little light does it throw on the real nature of the organism, that the earlier naturalists were unable to infer from it

certainly even whether they should regard the Sponge as an animal or a plant. Some, like Lamarck, supplied what was wanting by a free use of the imagination, and, supposing that the oscules were the mouths of cells occupied by little polypes, which constantly succeeded in evading observation, were enabled to class the Sponges with the Alcyonia; while some zoologists, who knew little about plants, handed over an organism which they did not understand to the care of the botanists. Nor was much help to be had from an examination of the Sponge in a living state; for, beyond mere growth, it presents no obvious signs of life. Marsigli was the first, in 1711, to observe the dilatation and contraction of the oscular openings, and afterwards Ellis asserted that he saw currents of water flow into them as well as out — a most exceptional occurrence — and thence inferred that the oscules were mouths by which the Sponge sucks in and squirts out water. In all this there was no progress, and it is to Robert Grant that we are indebted for the fundamental discovery which dispersed the mystery that had surrounded the physiology of the Sponge since the early time of Aristotle. His discovery consisted in the fact that he plainly witnessed currents of water containing floating particles of food flowing through the pores of the skin into the Sponge, and, at the same time, other currents of water, burdened with fæcal residues, flowing out of the oscules from the excurrent tubes. By this flow of water through it the life of the Sponge is manifested and maintained. The following is Grant's own account of his earliest observations:—

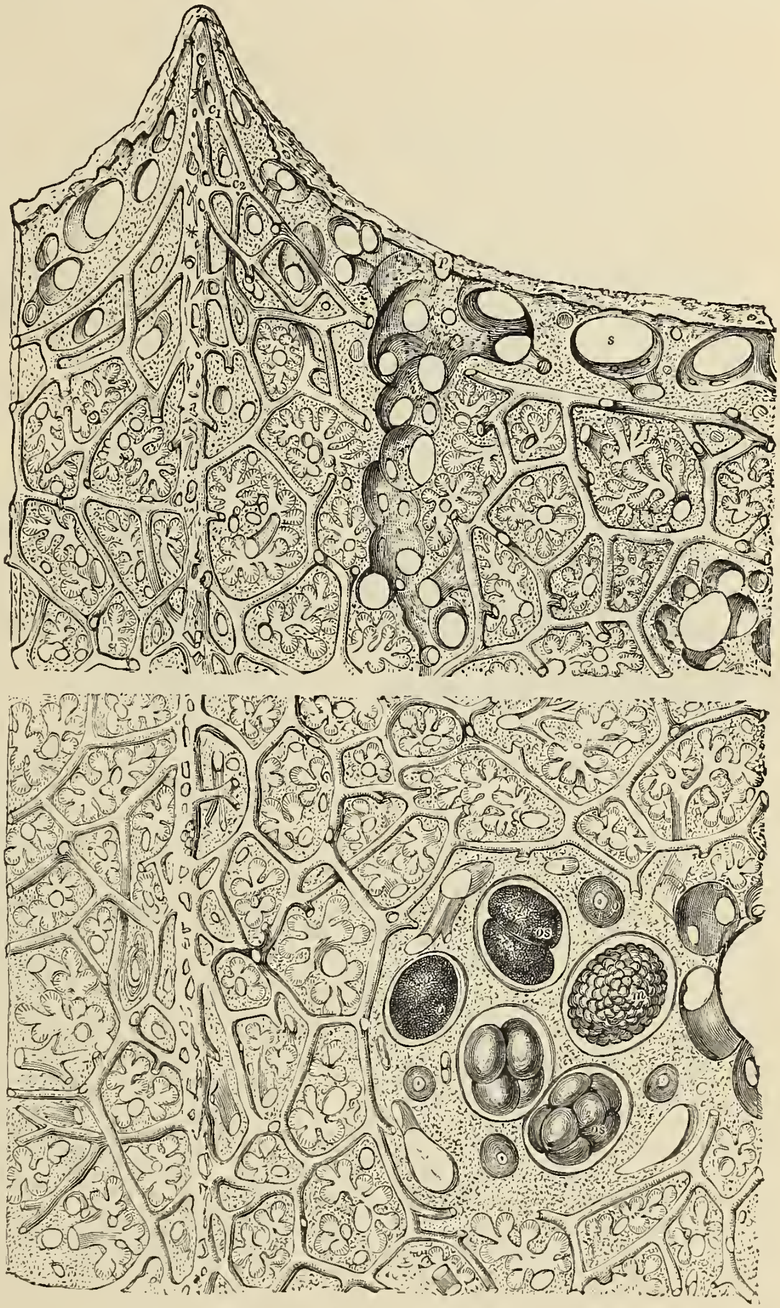


Fig. 1.—SECTION OF TURKEY BATH SPONGE. (*After Schulze.*)
p, Pore; *s*, subdermal cavity; *i*, incurrent canal; *f*, flagellated chamber; *c1*, chief fibre of the skeleton; *c2*, connecting fibres; *o*, ova in various stages of growth; *os*, ovum segmenting; *m*, a morula. (× 40.)

"In the month of November last, I therefore put a small branch of the *Spongia coalita*, with some sea-water, into a watch-glass, under the microscope, and, on reflecting the light of a candle

up through the fluid, I soon perceived that there was some intestine motion in the opaque particles floating through the water. On moving the watch-glass, so as to bring one of the apertures on the side of the Sponge fully into view, I beheld, for the first time, the splendid spectacle of this living fountain vomiting forth from a circular cavity an impetuous torrent of liquid matter, and hurling along, in rapid succession, opaque masses, which it strewed everywhere around. The beauty and novelty of such a scene in the animal kingdom long arrested my attention; but, after twenty-five minutes of constant observation, I was obliged to withdraw my eye from fatigue, without having seen the torrent for one instant change its direction, or diminish, in the slightest degree, the rapidity of its course. I continued to watch the same orifice, at short intervals, for five hours, sometimes observing it for a quarter of an hour at a time, but still the stream rolled on with a constant and equal velocity. About the end of this time, however, I observed the current become perceptibly languid, the opaque flocculi of feculent matter, which were thrown out with so much impetuosity at the beginning, were now propelled to a shorter distance from the orifice, and fell to the bottom of the fluid within the sphere of vision; and, in one hour more, the current had entirely ceased."

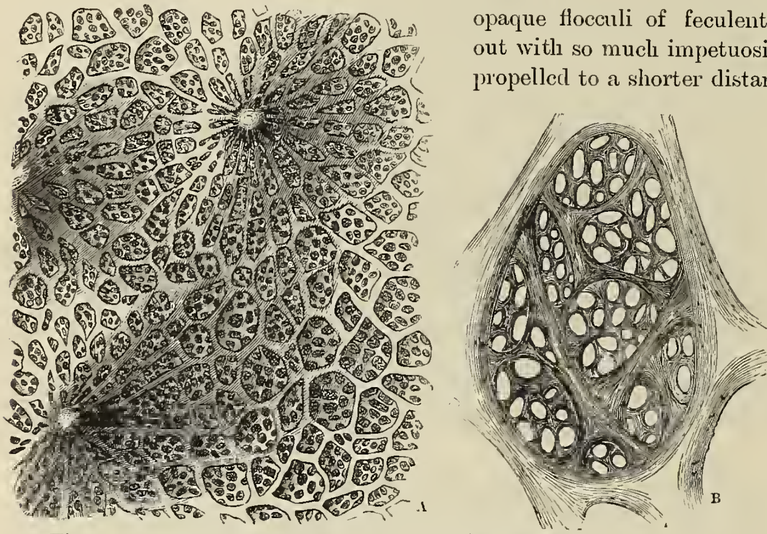


Fig. 2.—PORIFEROUS SURFACE OF A SPONGE (*Spongelia avara. After Schulze.*)
A, Magnified 10 diameters; B, a single mesh, × 60 diameters.

Grant afterwards observed the currents of water entering the pores, and illustrated his observations by a drawing, of which Fig. 3 is a facsimile copy. He then sought for the cause of the water-streaming, and rightly conjectured that it must be due to ciliary action, but sharp-sighted as he was he failed to find the cilia, though he especially looked for them. They were subsequently discovered, however, by Dobie, Bowerbank, and Carter, and the last showed that the cells bearing the cilia, or flagella, as these whip-like filaments are termed when each cell bears only one of them, are usually arranged in spherical chambers, to which he gave the name of ampullaceous sacs, but which are now more generally known as flagellated chambers. Finally, F. E. Schulze, in his faithful and beautiful illustrations of Sponge-structure, showed exactly how these flagellated chambers are brought into relation with the excurrent and incurrent canals; and this brings us back to the Bath Sponge. In this, as in most other Sponges, the terminal branches of the excurrent canals dilate at their ends into flagellated chambers (Fig. 4, C), about 0·001 inch in diameter, which are clustered about the penultimate branches of the excurrent canals like grapes in a bunch. The terminal branches of the incurrent canals apply themselves to the round ends of the chambers and open into them by one or usually more small circular pores. The flagellated cells are arranged in a single layer on the walls of the chamber, and rapidly lashing the water in one direction drive it into the excurrent canals; the multitudinous little streams so produced flow together in the larger excurrent tubes, and are finally discharged in a powerful current through the oscules. The water driven out of the chambers is replaced by an inflow from the incurrent tubes, and the loss from these is made good by the minute currents which stream through the dermal pores. These entering currents bear with them minute proteinaceous particles, such as minute infusoria, diatoms, and minute algæ; they also contain oxygen in solution; the outflowing currents carry away fæcal residues, and also the excreta urea and carbonic acid. The solid particles of food are ingested by the cells lining the excurrent canals, and particularly by the flagellated cells. This can most readily be proved by

feeding any kind of Sponge with carmine, killing it with osmic acid, hardening in alcohol, and then cutting from it thin slices for examination under a high power of the microscope. The flagellated chambers will then be seen clearly marked out from the rest of the Sponge by the abundant presence of the ingested colouring matter. So close a resemblance exists in all other respects between these cells and certain flagellated infusoria, that in all probability they also feed in the same way, and we may consequently describe the feeding of the Sponge-cell after that of the infusorian. The flagellum, then, of each Sponge-cell creates currents in the water towards itself, and the floating particles borne along with these come in contact with, and adhere to, a delicate film which surrounds the long neck of the cell like a collar (Fig. 5); the protoplasm of the collar is in a state of active circulation, streaming up one side and down the other like an endless band; the adherent food particles are thus carried by it to its base, where they come in contact with the neck, sink into its substance, and find their way into the basal part of the cell. A little drop of water is included with them, and thus the flagellated cells not only eat but drink; the food is next digested, and when all the goodness is got out of it, the fæcal residue is extruded by an extemporised aperture from the cell, and forthwith carried out of the Sponge by the outflowing currents. The circulation of the collar must expose a large and constantly changing surface to the surrounding water, and so allow of the absorption of oxygen and the escape of carbonic acid; this is one way in which the cell breathes. The proteinaceous compounds of the cell unite with oxygen, and in so doing liberate energy, which is partly expended in maintaining the movements of the flagellum and collar. The final products of the union of the protoplasm with oxygen are water, carbonic acid, and urea—the second useless and therefore in the way, the last a deadly poison; if the life of the cell is to be maintained, the carbonic acid and urea, together with the excess of water, must be got rid of or excreted. This is accomplished through the agency of one or more contractile vesicles, which alternately expand and contract, a slow expansion, during which water containing the other excreta accumulates in them, being followed by a rapid contraction by which it is expelled. Thus the flagellated cells eat, drink, breath, and excrete. They also grow and multiply in number; the excess of food which is not expended in producing energy leads to increase in size or growth, and this, when it passes a limit, gives place to division or fission, by which the cells are multiplied: the division may be either longitudinal or transverse; in the first case it increases the number of cells in the flagellated chamber; in the second one of the cells possesses an amœba-like character, and wanders into the main tissue of the Sponge, to be immediately described along with its other histological constituents.

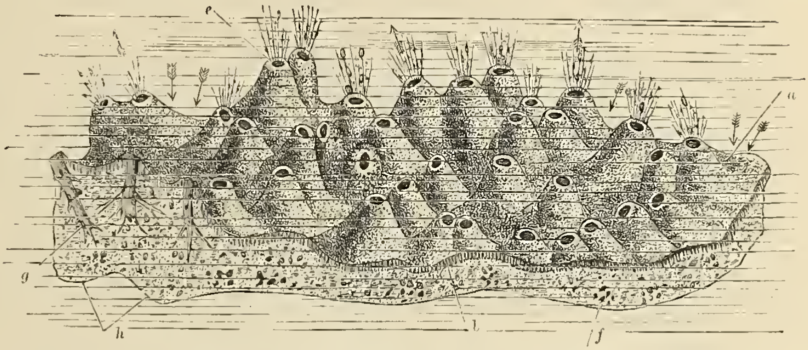


Fig. 3.—FAC-SIMILE OF GRANT'S FIRST FIGURE.

a, Pores; *e*, oscule; *f*, ova; *g*, embryo entering excurrent canals. The outward arrows show water escaping from oscules; the inward ones water entering the pores.

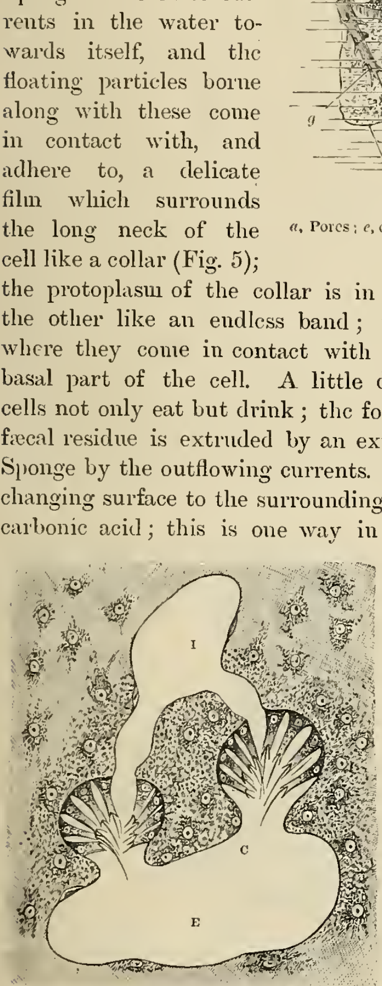


Fig. 4.—FLAGELLATED CHAMBERS (C) OF TURKEY BATH SPONGE IN CONNECTION WITH THE EXCURRENT (E) AND INCURRENT (I) CANALS. (*After Schulze.*)

The Sponge, like all other Metazoa, is ultimately resolvable into cells; and of these tissues are built up, which are arranged in three definite layers—the ectoderm, endoderm, and mesoderm. The ectoderm is a layer of flattened polygonal cells (Fig. 6, *ec*), which cover the whole exterior of

the Sponge, and line the incurrent canals throughout; the margins of the cells are usually invisible, but can be readily developed by treatment with nitrate of silver. The endoderm, or inner layer, lines the excurrent canals, and has the same structure as the ectoderm, except in the flagellated chambers, *i.e.*, the expanded ends of the smallest excurrent canals, where it forms a single layer of flagellated cells (Fig. 6, *en*). These consist of a spherical body of protoplasm, granular within, but firmer and clearer externally; containing a nucleus, and one or more contractile vesicles; one end is seated on the wall of the chamber, the other is prolonged into its cavity as a long neck of clearer hyaline protoplasm; around its margin the end of the neck extends into an immeasurably thin cylindrical or conical collar, while from its centre is produced a long slender flagellum.

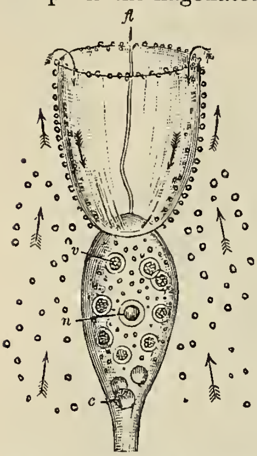


Fig. 5.—FLAGELLATE COLLARED INFUSORIAN FEEDING, × 2,000 dia. (*After Saville Kent.*)
The arrows show the direction of the current induced by the rotatory motion of the flagellum (*fl*). *v*, food vacuole; *n*, nucleus; *c*, contracting vesicle.

The tissue between the two preceding layers is the mesoderm (Fig. 4); it consists chiefly of a clear, greyish, jelly-like matrix containing irregularly stellate granular nucleated corpuscles, united by branching processes into an irregular network. In the neighbourhood of the flagellated chambers the definite outline of the corpuscles disappears, and they merge together, crowding the matrix with minute granules, amidst which the nucleus remains unchanged. This gelatinous connective tissue is very similar to that forming the disc of Jelly-fish; it originates in cells, which first become confluent, as about the flagellated chambers, and then change about their confluent margins into the jelly-like matrix, their central part, with the nucleus, remaining as the stellate corpuscle. In certain places, as around the oscular openings, and in the circular diaphragms, which at intervals constrict the main water canals, the corpuscles present a fusiform shape, acquire more or less distinct walls, and serve the function of muscle fibres. They present the same shape and appearances in other places, as parallel to the skeletal fibres, and directed lengthwise in the walls of the main canals but here their function is that of fibrous connective tissue. Besides these cells, which, though contractile, are not locomotive, there are other amœbiform cells which wander in the tissue, and frequently contain large granules looking like fat or starch, serving no doubt as food reserves.

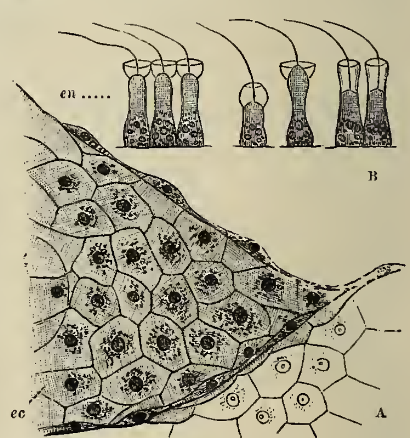


Fig. 6.—ECTODERM, AND DIFFERENT FORMS OF ENDODERMIC CELLS FROM SYCANDRA RAPHANUS. (*After Schulze.*)
A. *ec*, ectoderm; B, *en*, endoderm cells, × 500.

The skeleton, which is a product of the mesoderm, consists of a network of spongin fibres (Fig. 1), the substance of which in chemical composition most closely resembles silk, both compounds being regarded by chemists as horny matter. The fibres may be distinguished as chief fibres and connecting fibres; the former, radiately arranged, project at right angles to the Sponge-surface; the latter form a network transversely uniting the chief fibres together. Both have the same essential structure, consisting of a thick, transparent, concentrically-layered wall, and a soft granular axial thread; but the larger chief fibres contain in addition foreign particles, such as sand-grains, sponge-spicules, and fragments of shell. They are formed as a secretion by modified cells of the mesoderm; and the chief fibres obtain their included particles by imbedding, at their soft terminations, the foreign material which lies plentifully strewn over the skin.

Reproduction (Fig. 1).—The ova and spermatozoa are found in the mesoderm. The former commence existence as cells remarkably similar to the amœbiform corpuscles of the connective tissue, being chiefly distinguished by their large bladder-like nucleus and its large round nucleolus; as they increase in size yelk-granules make their appearance, and at length the egg assumes a regular ovoid form. It is noteworthy that the eggs in *Euspongia* are not, as in other Sponges, scattered irregularly through the mesoderm, but occur in groups of ten to twenty in number near the large excurrent canals embedded in a matrix of connective tissue, which is more or less separated from the rest of the

body by surrounding lacunar spaces. This seems to be an approximation to a rudimentary ovary. The eggs come to maturity at all times of the year. The spermatozoa (Fig. 7) occur in globular clusters, known as sperm-balls, each the product of a single cell; they are strewn through the Sponge and not collected in special areas.

Ova and spermatozoa are never developed, or at all events have not been observed, in the same individual, so that in the Bath Sponge, as in some other Sponges, though by no means in all, the sexes are distinct.

Development.—The entrance of the spermatozoon into the ovum, which constitutes the essential act of fertilisation, has not yet been certainly observed in this or any other known Sponge, but the resulting changes have been seen and carefully traced up to a certain stage. The ovum first divides into two similar cells, each of these again subdivides, and four similar cells result; subdivision again takes place and eight cells result, and this process of segmentation is continued till at length a spherical cluster of similar cells, the well-known mulberry-mass, or *morula*, is formed (Fig. 1). The morula then becomes differentiated into an inner mass of connective tissue cells, and an outer layer of small cylindrical cells, coloured by pigment granules, and each furnished with a flagellum. The flagellated embryo extricates itself from the parent Sponge, and whirls rapidly about in the surrounding water. It has a compressed oval form, and resembles the planula of some corals. Its further history is unknown.

Fig. 7.—SPERMATOZOA (*Halisarca lobularis*). [*After Schulze.*]
A, Separate spermatozoa, × 800; B, sperm ball, × 500.

Besides this natural mode of propagation the Bath Sponge can be multiplied, like a plant, by artificial cuttings. The demand in the arts for the Bath Sponge being in excess of the supply, attention has been directed to its cultivation, and with great success. The Sponge is cut into pieces, about one inch cube, care being taken to preserve as much of the skin and to squeeze out as little of the flesh as possible; the cuttings are then skewered on a strip of cane, and fastened into a wooden frame, constructed to preserve them from the access of mud and excess of light; they are then sunk in the sea at a depth of about five to seven yards. In about seven years' time a crop of fine regularly globular Sponges is ready for the market. A capitalist or a company is now all that is required to make Sponge farming a profitable pursuit.

Classification.—The species of Sponge in common use are three :—*Euspongia officinalis* (Lin.), the fine Turkey or Levant Sponge, just described; *Euspongia zimocca* (Schmidt), the hard Zimocca Sponge; and *Hippospongia equina* (Schmidt), the Horse Sponge, or common Bath Sponge. The genus *Euspongia* is distinguished by the regular development of the skeletal network throughout the body, its narrow meshes, scarcely or not at all visible to the naked eye, and the regularly radiate arrangement of its chief fibres; *Hippospongia* is distinguished by the thinness of its fibres and the labyrinthic character of the skeleton beneath the skin, due to its being closely traversed by numerous winding canals of about one-fifth to two-fifths of an inch in width. As a consequence its chief fibres have no regular radiate arrangement.

The species of *Euspongia* are distinguished as follows :—In *E. officinalis* the chief fibres are of different thicknesses, irregularly swollen at intervals, and without exception cored by sand-grains; in *E. zimocca* the chief fibres are thinner, more regular, and almost free from sand; in *E. officinalis* again the uniting fibres are soft, thin, and elastic; in *E. zimocca* denser and thicker—it is to this difference that the latter Sponge owes its characteristic hardness. Finally, the colour of the skeleton in *E. officinalis* is a light clear yellow, in *E. zimocca* a dark brown yellow. The common Bath Sponge (*H. equina*) has almost always a thick cake-like form, but its specific characters are not yet further defined.

Distribution.—*Euspongia officinalis* is found at various parts of the Mediterranean coast, as also are the other two species of Bath Sponge. A species not to be distinguished from it occurs also in the Caribbean Sea about the shores of the West Indian Islands, and associated with it are two

other species, the "yellow" and "hard-head" Sponges of the American shores, resembling *E. zimocca;* and the "wool" Sponge, which appears to be one or perhaps two species of the Hippospongia, *H. gossypina,* and *H. meandriformis,* the "velvet" Sponge.

GENERAL CHARACTERS OF THE SPONGIÆ.

In form and size Sponges vary greatly: some are no larger than a pin's head, others as much as four feet in height and breadth, while some attain a length of over six feet. In form they are massive; incrusting, sessile, or stalked; globular, branched, tree-like, with the branches free or united laterally into a network; lamellar, irregularly or fan-shaped; tubular, vasiform, or labyrinthic, many of the forms presenting a close parallelism to those of Corals. In some the form is constant and characteristic, as in the fairy-like Venus-basket (*Euplectella,* Fig. 9, A); the glass-rope Sponge with its cylindrical body (*Hyalonema,* Fig. 9, B); the open Flower-basket Sponge (*Dactylocalyx,* Fig. 9, E); or the great Neptune's Drinking Cup (*Poterion,* Fig. 9, C); but usually it is very variable; and since the same species may assume different forms, and the same form be common to different species, external shape is of very slight value in classification. The different forms can be derived from each other in many cases by quite easy gradations. Thus from a massive spreading Sponge may grow up finger-like extensions, and these, by branching, give rise to a tree-like form. By the subsequent union of the branches a net-like or clathrous stock results; or the finger-like elevations may widen into a lamella which, broadening as it grows, becomes fan-shaped; growing more rapidly on one face than the other, the fan becomes curved, and as the curvature increases the approximated edges at length touch and join together, producing a cup-like or vase-like form, the origin of which remains clearly indicated by a hole near the base, where the sides of the fan failed to reach, and still remain apart.

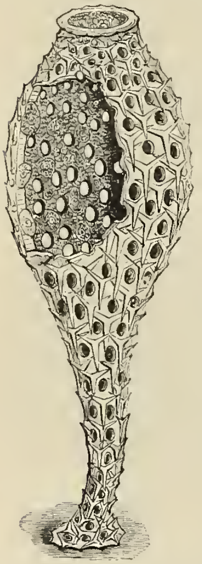
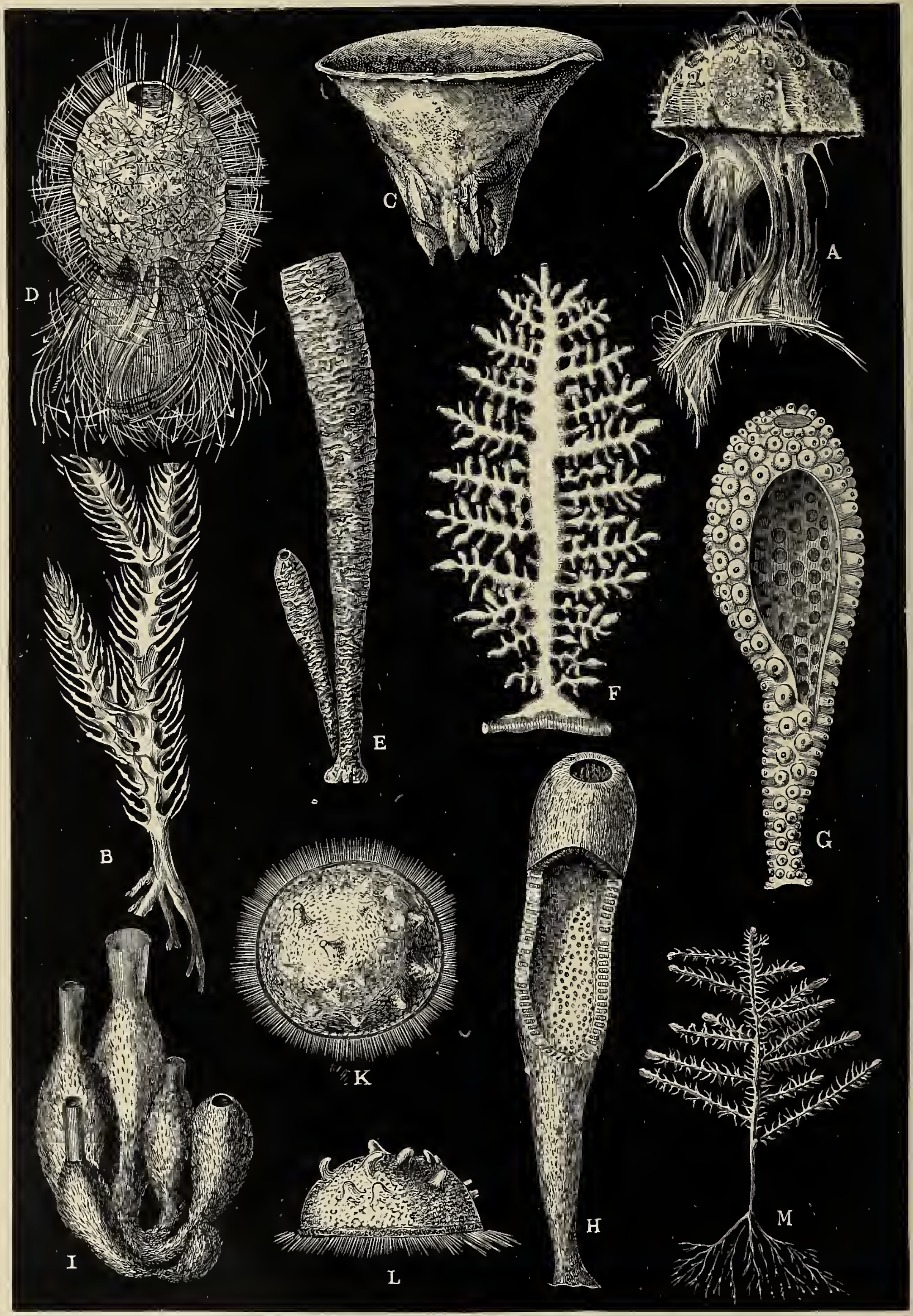


Fig. 8.—ASCETTA PRIMORDIALIS, × 50 dia. (*After Haeckel.*)

The mass which we speak of as the Sponge may consist of a single individual or several, just as a Coral may be single or compound, but it is not so easy in the case of the Sponge to determine what constitutes an individual. Usually the osculum is taken as the characteristic mark of a "person," but in some Sponges the osculum is absent (lipostomism) and the excurrent canal opens by the pores. In this case the excurrent canal must be regarded as indicating the individual, but again even this may disappear (lipogastrism), and then the question of individuality becomes as puzzling as it would be in a Coral which had lost all its polypes and consisted only of cœnosarc; in this case we must regard as an individual the whole Sponge mass. The colours of Sponges, which are very various, are usually due to the presence of pigment granules imbedded either in the endosarc of the flagellated cells, or in the mesodermic cells, usually of the skin only, but sometimes of the whole body. The various tints range through the whole octave of colour, the commonest perhaps being various shades of yellow and brown; grass-green and orange-red are frequent; rose red, faint lilac, deep carmine, sky-blue, indigo, black, are also not rarely met with, as well as all the colours of flowers and of the leaf from the bud to the fall. Sometimes the colour of the same species differs in different localities, as in *Ascetta clathrus,* which, though usually grey, is sometimes sulphur-yellow or vermilion-red. Many Sponges are white as snow, and, for the same reason, their minute colourless transparent spicules scatter the incident rays of light, just as the tangled crystals of a snow-flake do. Occasionally the colour of the Sponge is accidental, as when it depends on that of ingested food particles, or of parasitic algæ.

Those pigments which belong to the chlorophyll group no doubt play the same part here as they do in plants, protecting the protoplasm (which is able to build itself up from carbonic acid, water, and ammonia under the action of sunlight) from the destructive effect of the violet rays; the parasitic algæ are probably of great service to the Sponge, both in absorbing its excreted carbonic acid, and liberating oxygen for its use.

The Canal System.—Although the type of canal system described in Euspongia is by far the



SPONGES.

A, Thenea Wallichii—a Choristid Tetractinellid (*After Thomson*); B, Chondrocladia virgata—a Desmacidine Monaxonid (*After Thomson*); C, Askonema Setabalense—a Lyssakine Hexactinellid (*After Thomson*); D, Rossella velata—a Lyssakine Hexactinellid (*After Thomson*); E, Luffaria Archeri—a Ceratine Cerospongia (*After Higgin*); F, Ascandra sertularia—an Ascon Calcisponge (*After Haeckel*); G, Sycetta primitiva—a Sycon Calcisponge (*After Haeckel*); H, Sycortis levigata—a Sycon Calcisponge (*After Haeckel*); I, Sycometra ciliata—a Sycon Calcisponge (*After Haeckel*); K, Trichostemma hemisphericum—a Suberite Monaxonid (*After G. O. Sars*); L, Ditto, from the side; M, Cladorhiza abyssicola—a Desmacidine Monaxonid (*After G. O. Sars*). Figs. F, G, I, are magnified; all the rest reduced in size.

most widely distributed amongst the Sponges, it is, at the same time, the most complicated. In its simplest expression, the canal system is found amongst the lower members of the Calcispongiæ, as in the little *Ascetta blanca* (Fig. 8), discovered by Micklucho Maclay. This is simply an oval sac, with a large internal cavity, and very thin walls, opening at one end by an osculum, attached at the other, and perforated all over by numerous short pore canals. The endoderm consists entirely of flagellated cells, so that these line the whole interior, and driving the water out at the mouth, cause an influx through the pores, which are mere fluctuating apertures, with no constancy in position. There are here no true incurrent canals, and the whole Sponge might be compared to a magnified flagellated chamber with a surrounding layer of mesoderm and ectoderm. Haeckel regards it as similar to a

Fig. 9.—A, EUPLECTELLA SUBEREA (*After Thomson*); B, HYALONEMA SIEBOLDII (*After Schulze*); C, POTERION (*After Harting*); D, SIPHONIA PYRIFORMIS (*After Sowerby*); E, DACTYLOCALYX STUCHBURYI (*After Sollas*).

single Hydrozoon. Neglecting the spicules which are embedded in its mesoderm, Ascetta might be regarded as an embodiment of just so much as is common to all the Sponges, a concrete definition of the group.

From this simple stage the more complicated appear to arise in two ways; in one, which is characteristic of the small group of Sycones, buds, repeating in every way the structure of the parent, sprout out at right angles from the wall of an Ascon such as *Ascetta;* to the central cavity of these the flagellated cells become restricted, those of the original Ascon becoming converted into polygonal pavement cells; the central cavities of the buds remain in free communication with that of the parent. The latter is now the excurrent canal, the former the flagellated endings or branches of it. (Plate 71, Fig. G.) In more integrated forms the buds grow close together, touch, and unite along the lines of contact, the narrow canal-like interspaces left between them serving for the conduct of water to the pores, and constituting an incurrent canal system. (Plate 71, Figs. H, I.)

Precisely how complication ensues in the other case, which is that of the great majority of Sponges, is not quite so clear; but it would appear that from the endoderm of a sac resembling an Ascon hollow buds are formed, which project into the mesoderm. These are the flagellated chambers.

A folding of the entire wall of the Sponge follows (this is an irregular form of budding), and converts the originally simple central cavity into smaller canal-like spaces, in other words, it becomes a branched excurrent canal system; the interspaces between the folds outside the Sponge wall become the incurrent canal system.

Histology.—The ectoderm appears to maintain its pavement epithelial character very constantly, but sometimes its cells become flagellated, as in *Halisarca* and *Plakina.* The endoderm undergoes no great variation. The mesoderm, on the contrary, differs a good deal in different Sponges; in many it consists, as in *Euspongia,* of a clear jelly-like matrix, embedding branched granular corpuscles; in others it becomes densely charged with minute granules, maintaining throughout the character it presents locally about the flagellated chambers of *Euspongia,* while in some it appears to consist of separately-outlined granular cells. The clear granules, which fill some of the wandering amœbiform cells, are, in some cases, certainly starch. The fusiform cells of the mesoderm are often abundantly developed, and sometimes form a thick layer beneath the skin, having the appearance of fibrous connective tissue, but where the main water-canals pass through it, this layer is modified to form around each of them a distinct sphinctral muscle.

The Skeleton.—The character of the skeleton is wonderfully diverse, and since it is fairly constant within each species it affords us the best means of classification. Some Sponges, such as *Halisarca,* are entirely destitute of a skeleton, others (Lithistids) are possessed of one of stony hardness, which no one would think of applying to skin except as a counter irritant. The skeleton may consist of a network of horny fibres, the axis of which is either filled merely with soft granular matter, or includes also foreign bodies, often to such an extent as to convert the fibre into a veritable rope of sand; or, instead of foreign bodies, a core of proper spicules, *i.e.,* spicules produced by the Sponge itself, may be present; and the spicules may increase in number, and the horny matter diminish in quantity to such an extent, that the fibre comes to consist only of spicules. The skeleton frequently consists wholly of spicules, but these are far from being always arranged in a fibrous form. The spicules, which are of most diverse forms, are composed of an organic basis (spiculin), densely impregnated or chemically combined with a mineral salt—carbonate of lime in the case of calcareous spicules, silica in that of silicious spicules. This distinction in mineral composition was discovered by Robert Grant. The spicule usually consists of a clear glassy wall, concentrically-layered, enclosing a soft thin axial thread.

It will be convenient to state here that according to the character of their skeleton, the Sponges may be divided into the following four orders :—

*Myxospongiæ.**—Soft Sponges, skeleton absent.

Calcispongiæ.—Skeleton consists of calcareous spicules, never united to form a fibre.

Silicispongiæ.—Skeleton characterised by silicious spicules, which may or may not be united into a fibrous skeleton.

Cerospongiæ.—Skeleton consists of a network of horny fibres, sometimes including foreign particles, but never proper spicules.

The simplest form of spicule is needle-shaped (acerate), pointed at both ends (Fig. 10, *a*). It grows lengthwise from the middle along a single axis in the direction of the ends; it is thus uni-axial but bi-radiate. Supposing it to cease to increase in length at one end, it becomes an acuate spicule (Fig. 10, *b*), still bi-radiate, but the radii of unequal length; if one radius does not develop at all and is represented only by a globular enlargement, a pin-headed acuate results (Fig. 10, *c*), which is both uni-axial and uni-radiate. If a third ray grows out from the side of the acerate spicule, a tri-radiate but bi-axial spicule is the result (*d*); should all three rays diverge, so that no two are in the same straight line, we have the tri-radiate and also tri-axial form (*e*) so characteristic of the Calcispongiæ, though by no means confined to them, since it occurs normally in many of the Silicispongiæ, *e.g.,* the Plakinidæ, Plectronellidæ, and Sphinctrilla, and, as a variation, common, but abnormal, in a great number of other instances. If a fourth branch or ray is produced from the centre, not in the same straight line as any of the others, a quadri-radiate (also quadri-axial) form appears, and this characterises the sub-order *Tetractinellidæ,* though it appears also in Sponges belonging to other groups. The four rays may remain of the same value (*f*), and be disposed without any ascertained relation to the form of the Sponge and its canal system (Pachastrellidæ), or one ray may become distinguished from

* Greek, *myxa*, slime.

the rest by excess or defect of development, as the shaft (g to j), the other three remaining similar to each other being known as the rays or arms. The shaft usually takes a radiate direction in the Sponge, at right angles to the surface, with which the rays, on the contrary, lie more or less parallel; the point of the shaft is directed inwards towards the centre of the Sponge, the head or rayed end outwards. The rays may grow backwards, recurved, giving the spicule a grapnel-like form (g), or forwards, fork-like, or outwards at right angles to the shaft; they may remain simple, or bifurcate once (h), or more rarely, twice, or even trifurcate, as in a few recent and some fossil forms; finally, they may broaden out in the surface of the Sponge into thin lobate expansions (i), and these may become confluent in a circular disc (j), in which, however, the tri-radiate origin can still be traced by the

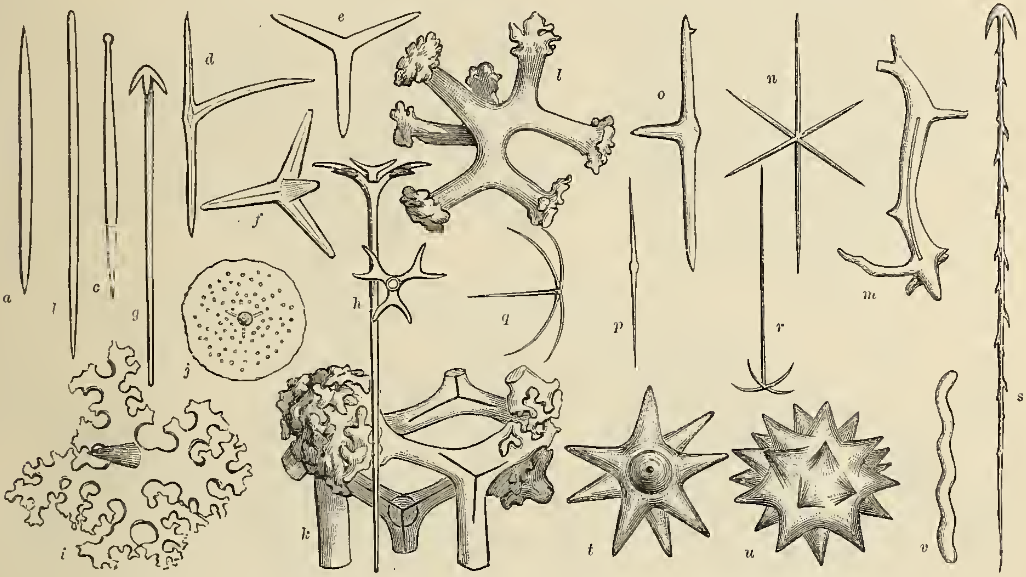


Fig. 10.—VARIOUS FORMS OF SPONGE SPICULES. (*After Bowerbank, Zittel, and others.*)

form of the axial thread. Returning to the quadri-radiate form, in which the rays are all similar (f), another series of changes may result by the ends of the rays becoming branched (l), and closely interlocking with those of their nearest neighbours. In this way the firm stony network characteristic of the Lithistids is produced (k). These branched spicules may be traced through various modifications till their quadri-radiate form remains no longer recognisable (m).

Another group of forms originates in growth in six directions from a common centre along three axes at right angles to each other. The sex-radiate spicule so produced is characteristic of the Hexactinellidæ (n). One by one the rays of this form may be suppressed (o), so that mingled together in the same Sponge sex-, quinqi-, quadri-, tri-, and bi-radiate spicules may be found, the bi-radiate or acerates (p) often still showing signs of their sex-radiate derivation by the cross-like form of the axial-thread in the middle of the spicule.

By suppression of the distal ray of the sex-radiate type, nail-like spicules arise (q), the shaft being stuck in the substance of the Sponge, and the four rays spread out in the skin, forming, with the similar rays of adjacent spicules, a square meshed dermal network. The shaft of such a spicule may become greatly elongated (r), and then it often serves with others for anchoring or supporting the Sponge in the slimy ooze of the sea floor on which it lives. If the four rays of such a spicule become recurved and much reduced in size, we have a grapnel-headed anchoring spicule (s), such as those which compose the twisted wisp-like bundle of the glass-rope Sponge (*Hyalonema*), and which, measuring eighteen inches in length, are probably the largest spicules known.

If growth from a centre takes place radiately in a large number of directions, a stellate spicule (t, u) results; fine examples of this are known in *Tethya*. By growth along a constantly changing axis various curved forms are produced (v).

Besides the foregoing large spicules, which, as a rule, form the chief skeleton of the Sponge, other much smaller ones exist (Fig. 11), which, because they are seldom united into a coherent skeleton, but occur dispersed throughout the mesoderm, have been termed flesh spicules, a term not unopen to objection. Many of these simply repeat the forms of the large spicules, but altogether they present a greater diversity and frequently also a greater complexity of form. The minute acerate (*a*) by curvilinear growth becomes tricurvate (*b*) or bow-shaped, or hamate (*c* and *d*), or sinuate (*e*); the sinuate, if spined all over, is a spini-spirula (*e*); and from this we seem to pass to a straight spicule with whorls of spines (*sceptrella*, *g*), or to a spined globule (*globostellate*, Fig. 10, *u*). The C or bow-shaped spicules, by various modifications of their ends, give rise to various forms

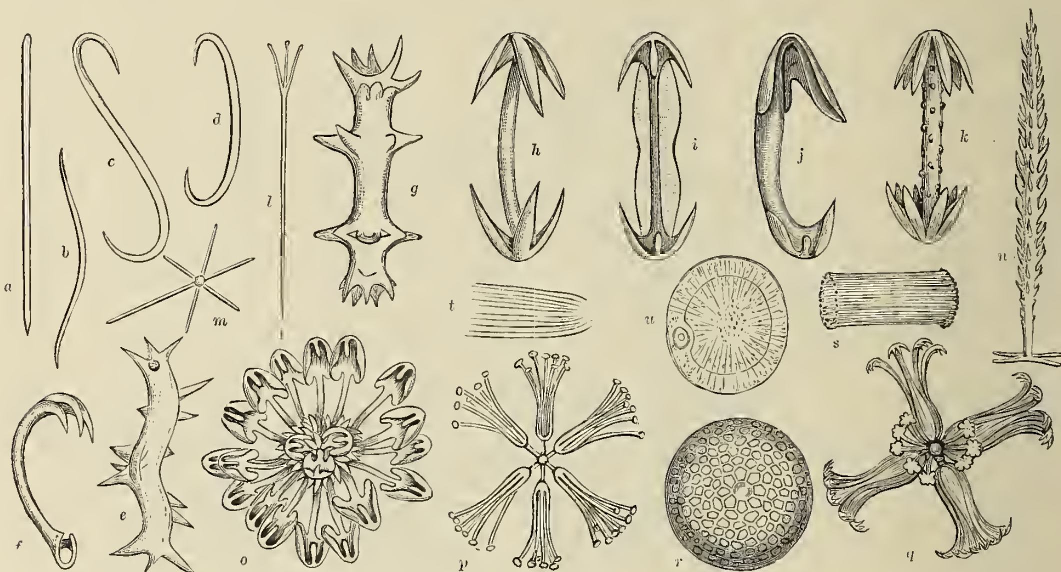


Fig. 11.—VARIOUS SMALLER FORMS OF SPONGE SPICULES. (*After Bowerbank, Schmidt, Sollas, and others.*)

known as anchorates (*h*, *k*), distinguished as equi-anchorates, if the ends are equal and similar (*h*, *i*), inequi-anchorates, if one is smaller than the other (*f*, *j*). The inequi-anchorates are sometimes clustered together into radiate groups, the small ends meeting at the centre, and the larger diverging at the margin. Rosettes of remarkable beauty (*o*) so produced are common in *Esperia*. The small spicules of the *Hexactinellidæ* are, like the large, characteristically sex-radiate; they may be regularly and simply six-rayed (*m*), or the rays may divide into two, three, or more straight or curved secondary rays, the ends of which may be pointed or capitate (*p*, *q*). The anchorates (*k*) of this group are represented by a form which is not obviously sex-radiate; it consists of a central shaft with eight re-curved arms at each end; it sometimes is found in rosettes like the inequi-anchorates of Esperia. In this group occurs a nail-like spicule, with a cruciform head, the shaft of which is covered with large spines, all pointing towards the end; these "wheat-sheaf" spicules (*n*) adorn the margins of the oscules of *Meyeria*, the heads being embedded in the skin and the points projecting into the oscule. The broom-shaped spicules shown in the figure (*l*) are characteristic of some Hexactinellids.

Finally, various forms of multi-radiate small spicules are plentiful, the simplest of which consists of a number of fine, hair-like rods (trichites), developed in a fasces-like bundle (trichite sheaf), within a single cell (*s*, *t*). In other forms, the trichites grow radiately outward from a common centre, and, becoming thickened with age, produce a trichite-stellate, or, if they are very numerous, a trichite-globate or globate spicule (*r*, *u*). The globate is characteristic of the most highly developed and complicated of all Sponges, viz., the Geodina. It commences as a minute ball of trichites, the inner ends of which are fused into a little globule at the centre. It is developed within a single cell, with a large nucleus (*u*), and, as it grows, the trichites becoming longer and

stouter, the nucleus remains a little behind in a shallow depression, marked on the adult globate as the "hilum." After the trichites have become strong spines, they grow rounded at the ends, then toothed and roughened for the attachment of ligamentous fibres.

Embryology (Figs. 12, 13).—Notwithstanding the attention which has been paid to the embryology of the Sponges, it is still impossible to bring our knowledge on the subject under a single large

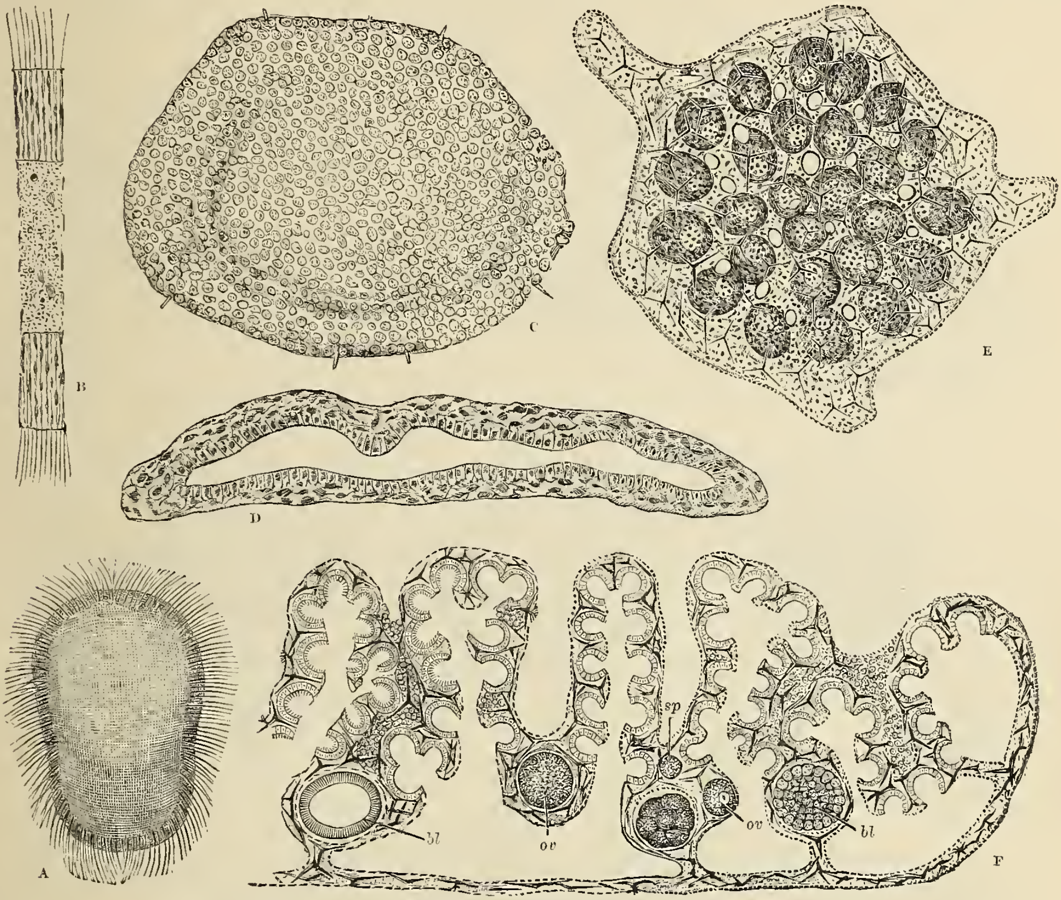


Fig. 12.—DEVELOPMENT OF A SILICIOUS SPONGE (*Plakina monolopha*). [*After Schulze.*]

A, Free-swimming Planula; B, section of the same, showing epiblast and hypoblast; C, fixed planula with a gastric cavity; D, section of the same a little older; E, young sponge, showing pores and flagellated chambers; F, section across the adult sponge, showing (*sp*) sperm ball, (*ov*) ova in different stages of development, and (*bl*) blastula.

generalisation. Two distinct modes of development have been so far fairly made out, but it yet remains to be seen how far all Sponges conform to these, and how they are related to each other. The ovum in all cases divides first into two, then four, and next eight segments, which, however, are not always equal and similar; by further subdivision, it gives rise either to a solid cluster of cells like a mulberry (morula), or a hollow spherical cluster, the cells forming a single layer about a central cavity (blastula), which normally is completely closed, but, in one instance at least, is known to be open at the poles. The course of development may now become very different, according as a *Planula* or an *Amphi-blastula* is next formed. The planula is a solid embryo (Fig. 12, A) of two layers of cells—an inner, or hypoblast, consisting usually of gelatinous connective tissue, with its stellate corpuscles, and an outer, or epiblast, consisting of small, cylindrical, flagellated cells. The hypoblast originates either by metamorphosis of the internal cells of the morula, or by the budding of fresh cells, which subsequently become metamorphosed, from the inner ends of the cylindrical cells of the blastula. The planula at this stage usually escapes into one of the incurrent canals of the mother Sponge, and is carried out by the outflowing currents into the surrounding water, when it swims

briskly about by the movements of its flagella. It then settles down on some solid body, and flattens out into a disc, which becomes attached by pseudopodia-like extensions from the flagellated cells around its margin. The flagellated cells, losing their flagella, form the pavement-like cells of the ectoderm. Soon after attachment, the hypoblast splits in the middle, and the cleavage cavity so produced becomes lined by flagellated cells differentiated from the hypoblast (Fig. 12, C, D). This layer of cells is the primitive endoderm, the remainder of the hypoblast is the mesoderm. The endoderm buds off flagellated chambers into the mesoderm, and becomes itself converted into plate-

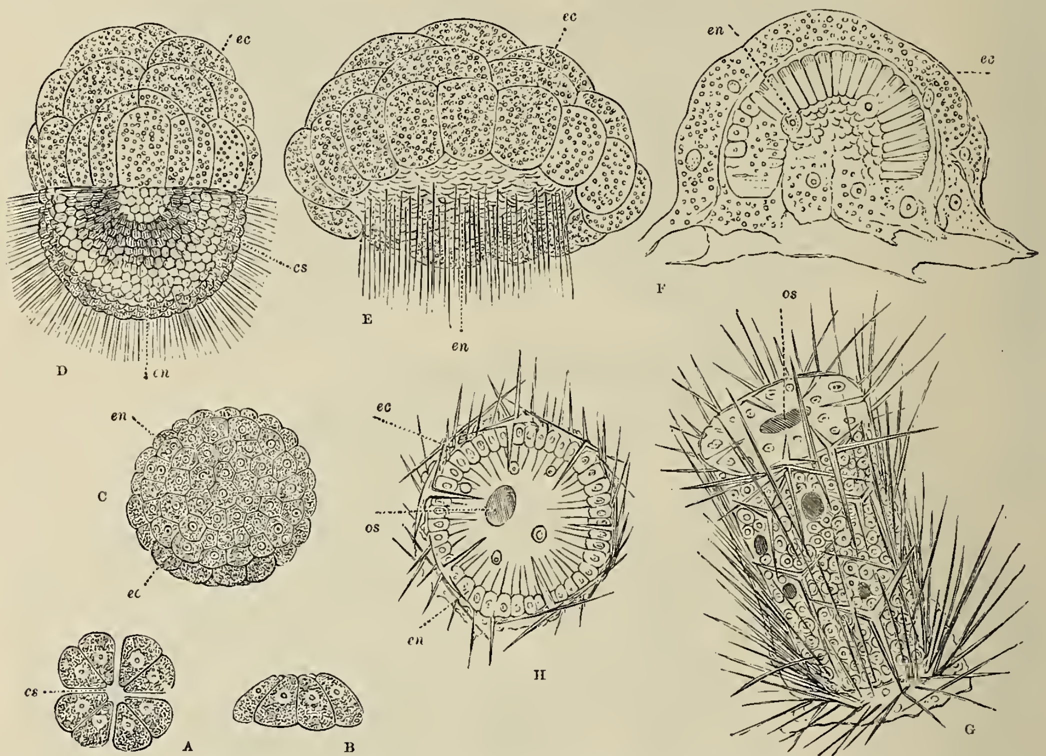


Fig. 13.—DEVELOPMENT OF A CALCAREOUS SPONGE (*Sycandra raphanus*).

A, B, Ovum segmented into eight cells; C, side view of embryo in the blastula stage, eight of the granular cells which give rise to the ectoderm of the adult are present at the lower pole; D, amphiblastula stage; E, a later stage, after the ciliated cells have commenced to become invaginated; F, fixed gastrula stage. The figure shows the amœboid ectoderm cells (*ec*) derived from the granular cells of the earlier stage, and the columnar endoderm cells, lining the gastrula cavity, derived from the ciliated cells of the earlier stage; the larva is fixed by the amœboid cells on the side on which the original mouth opening is situated; G, H, the young sponge shortly after the development of the spicules; G, view from the side; H, view from the free extremity. *os*, osculum; *ec*, ectoderm; *en*, endoderm, composed of ciliated cells; *cs*, segmentation cavity. The terminal osculum and lateral pores are represented as oval dark spaces in G, H.

like epithelial cells; pores appear in the walls, and put the flagellated chambers in communication with the exterior (Fig. 12, E), and subsequently an osculum is formed. By a folding of the outer wall, and other changes, a simple excurrent and incurrent canal system is produced (Fig. 12, F).

The amphiblastula (Fig. 13, D) is a hollow sphere, one hemisphere formed of a single layer of small, transparent, cylindrical, flagellated cells (epiblast), the other of large, granular, rounded, and not flagellated cells (hypoblast). It results from a metamorphosis of the blastula (Fig. 13, C), the cells of which, for the greater part, are converted into the small flagellated cells, while a few at the base become granular, and by multiplication produce the larger rounded cells. The next step in the development of the amphiblastula is most interesting and important: the flagellated cells become gradually withdrawn or invaginated into the hemisphere of granular cells; the central cavity of the amphiblastula is thus obliterated, and replaced by another surrounded by the flagellated cells (Fig. 13, E). The embryo now resembles a gastrula of one of the higher animals, consisting, as it does, of a sac with a two-layered wall, and a central cavity communicating with the exterior by a mouth. It soon settles, mouth downwards, on some foreign object (Fig. 13, F), the outer granular cells become the ectoderm, with its usual characters, the inner flagellated cells the endoderm, and a mesodermic layer appears

between the two, probably derived from the epiblast. The embryo now lengthens into a cylindrical form, pores appear in its sides, and an osculum opens at the free end, the primitive mouth having become closed soon after the attachment of the larva (Fig. 13, G, H).

The spicules of the Sponge always develop in the mesoderm, probably in all cases, certainly in some, as the products of single cells. It is a curious fact that they appear in the embryo before it becomes attached, sometimes even before it has left the body of its parent.

Classification.—The position of the Sponges in the organic world was long the subject of controversy, and it was not till after the fundamental discoveries of Robert Grant, in 1825, that their right to a place in the animal kingdom was universally admitted. After the difficulty which had been experienced in making good their claims to an animal nature, it would naturally be expected that they would be assigned but a very lowly place amongst their recognised associates, and accordingly we find them originally relegated to the Protozoa, the lower of the two sub-kingdoms into which the animal world is now divided, the other being known as the Metazoa. The embryological history of the Sponge, and the sub-ordination of its individual cells to the unity of the complex whole which they form, ensured for them, however, the highest place in the sub-kingdom. But they were not long allowed to enjoy an ignoble repose. Already, in 1854, Leuckart advanced them into the higher sub-kingdom as members of the Cœlenterata. At that time, however, naturalists were not prepared to acknowledge the justness of this promotion, and it was not till Haeckel, in a brilliant but too imaginative work, came forward in its support, that it found any general acceptance. Previously, however, in 1866, Professor James Clark had been led, by his discovery of the resemblance of the collared cells of the Sponge to the flagellated infusoria, to regard the Sponges as mere aggregates of these Protozoa, but this view, though earnestly supported by Carter and Saville Kent, is opposed to the general opinion of most naturalists. The searching investigations into the structure and embryology of the Sponges since the publication of Haeckel's views, leave little doubt as to their Metazoic nature. But with regard to the nearness, or otherwise, of their relations to the Cœlenterata, the greatest doubt still exists. The writer originally regarded them as Cœlenterata, which differ from all other members of the class, in the fact that their embryos attach themselves by their oral instead of their aboral extremity, but in spite of certain remarkable resemblances of the larvæ to those of the Cœlenterata the balance of evidence seems in favour of those who, with Balfour, regard the Sponges as forming a separate class, quite independent of the Cœlenterata, and situated at the very bottom of the Metazoic sub-kingdom.

For the subdivision of the Sponges into smaller groups we are chiefly indebted to Oscar Schmidt and Carter, not to forget Haeckel. The accompanying table is founded chiefly on the classifications proposed by them, with modifications, which may possibly be found convenient.

CLASS SPONGIÆ.

Orders.	*Sub-orders.*	*Families.*
MYXOSPONGIÆ		Halisarcidæ. Chondrosiadæ.
CALCISPONGIÆ		Ascones. Leucones. Sycones.
SILICISPONGIÆ	Monaxonidæ	Renierinæ. Suberitidinæ. Desmacidinæ. Echinonemata. Chalinidæ.
	Tetractinellidæ	Choristidæ. Lithistidæ.
	Hexactinellidæ	Lyssakina. Dictyonina.
CEROSPONGIÆ	Ceratinidæ. Psammonemata.	

MYXOSPONGIÆ.

The *Halisarcidæ*,* characterised by the entire absence of any skeletal parts, are represented by the single genus *Halisarca*, comprising a number of small smooth soft Sponges, which grow in

* Greek, *hals*, *halos*, the sea, *sarx*, *sarcos*, flesh.

irregular crusts of beautiful colours; sky-blue to violet, russet-red to flesh-colour, pale yellow, carmine, and purple tints being common, though some are colourless.

The *Chondrosiadæ** are provided with a rough external rind of fibrous connective tissue, and one of the two genera of which the family consists is furnished with stellate silicious spicules; it should therefore be placed in the Silicispongiæ, of which it, as well as the remaining genus, which is devoid of hard parts, is probably a degraded descendant.

CALCISPONGIÆ.

These are a small but compact group, which has been closely studied by Haeckel, whose brilliant monograph on the "Kalkschwamme," though marred by a vicious confusion of fact and fancy, has both by its fancies and its facts given a more powerful impetus to the investigation of the whole group of Sponges than any work which has appeared since the time of Robert Grant.

The skeleton here consists of calcareous spicules of various forms, acerate, tri-radiate, and quadri-radiate, the tri-radiate being the most characteristic: they are never collected into fibres nor united together by spongin, but occur separately immersed in the soft tissue of the Sponge, so that after the death and dissolution of the organism they at once fall asunder, and being at the same time very soluble in sea water are so quickly destroyed that it is very doubtful whether they are capable of being preserved in the fossil state. Up to this time no fossil Sponge unquestionably belonging to the Calcispongiæ has been described.

They are mostly very small Sponges, often of very regular geometric form; usually white, though sometimes brilliantly coloured.

The Ascones† are simple sacs, with a completely flagellated endoderm; they may be single (Fig. 8), or branched (Plate 71, Fig. F), or in other ways united into a common stock. The Sycones‡ are composite sacs, derived from the Ascones by a budding of Ascon-like sacs radiately from the wall of a parent Ascon (Plate 71, Fig. G). It is a fact of great interest for the theory of development that a continuous or transitional series of species can be shown to exist between a simple Ascon and a Sycon in which the radiate buds have all united together by their lateral surfaces to form a complex tubulated wall (Plate 71, Figs. H, I); and especially that this most complex Sycon passes through the various stages exhibited by these species in the course of its individual development.

One of the common animals of the sea-shore is the little purse-shaped *Sycandra* (*Grantia*) *compressa*, which occurs hanging mouth downwards from the under-surface of rocks, or their attached seaweeds, between tide levels. Sections can easily be made of this to show the tubulated structure of the wall, and by boiling it in caustic potash for a minute or two its beautiful calcareous spicules can be freed from the soft tissues for examination under the microscope. The Leucones§ are characterised by a complicated water canal system, which appears to belong to the same type as that of Euspongia and the majority of the Sponges. The snow-white crusts of *Leucandra nivea* are by no means rare on the under surface of between-tide rocks on our coasts.

The Calcispongiæ have a world-wide distribution, and are found from the sea-level down to a depth of 342 fathoms. Of the 111 species described by Haeckel, nine are cosmopolitan, 68 are found exclusively in the Atlantic, 12 in the Pacific and 22 in the Indian region. No doubt the greater richness of the Atlantic region is due to its having been more thoroughly investigated than the others.

SILICISPONGIÆ.

In this order, characterised by silicious spicules, the Sponges attain their fullest expression and highest development. Its members are the most numerous, the most diverse, and some of them the most complicated of the class. They are spread through all seas, at all depths, and were already in existence in the early Cambrian times. The only family of Sponges (*Spongillina*) which inhabits fresh water belongs to them, and this inhabits the rivers of most existing continents.

The *Monaxonidæ* (usually known as the Monactinellidæ, which is a misnomer, since it is the one-axedness of their spicules, not their one-rayedness, which characterises them) are distinguished by the presence of uni-axial, and the absence of tetractinellid and hexactinellid spicules. If quadri-radiate spicules do occur in some genera they differ from those of the genuine Tetractinellidæ in the

* Greek, *chondros*, gristle. † Greek, *ascos*, a wine-skin or leathern bottle. ‡ Greek, *sycon*, a fig. § Greek, *leucos*, white.

fact that the three additional rays are given off from the hinder (proximal) end of the shaft and not from the anterior (distal).

By Oscar Schmidt this sub-order is divided into the five following families:—

Families, O.S.	*Orders, Carter.*
Renierinæ, Desmacidinæ, Suberitidinæ	Holorhaphidota.
Chalinopsidinæ	Echinonemata (pars)
Chalineæ	Rhaphidonemata.

Carter's classification of these Sponges is shown in the table.

In the Renierinæ* the chief spicules are usually bi-radiate (acerate), and are generally collected to form fibre, in which they are arranged like the elongated cells in the woody fibre of plants. Spongin may develop about this fibre, cementing the spicules together, and then the Renierine becomes a Chalinine Sponge, but so easy is the transition between these families that Carter makes mention of a Sponge which is Renierine or Chalinine, according to the locality in which it is found. The Renierinæ are among the commonest of Sponges, and are well represented on the British coasts; the hardy *Amorphina panicea*, or "Crumb of Bread" Sponge (Fig. 3), found at most watering-places, is a good example. It grows in thick crusts, of a plant-green colour, rising into little conical volcano-like elevations, which open by an oscule at the summit; pores occur in the skin over the interspaces of a very regular spiculous network which lies beneath. Its spicules are simple accerates, sharply pointed at each end, and crowded loosely together into indefinite fibre, which forms an altogether irregular network in the body of the Sponge. From this loose texture, and the fact that owing to the absence of spongin, the Sponge readily crumbles between the fingers when dry, it derives its name of "Crumb of Bread" Sponge.

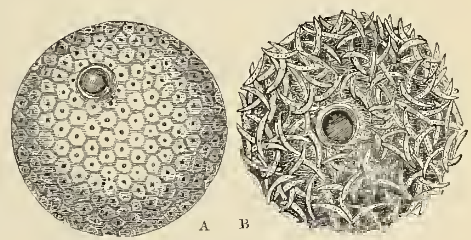


Fig. 14.—STATOBLASTS OF SPONGILLA.

A, Statoblast of *S. fluviatilis*, in its natural state × 50; B, of *S. lacustris*, after treatment with nitric acid × 90.

Another common example is the *Spongilla fluviatilis* of our rivers. It occurs in irregular masses of much the same colour as *A. panicea*, with which it closely agrees in general structure; it differs, however, in common with the sub-family Spongillina, to which it belongs, both from that and all other Sponges, in the fact that it reproduces itself not only by ova, but by curious little bodies (Fig. 14) known as winter-eggs, or statoblasts, which somewhat resemble the statoblasts of the Polyzoa. Their history has been the subject of a classic memoir by Carter, who finds that they originate near the base of the Sponge, by certain cells congregating together and becoming surrounded, except at one point, by a spherical shell, a pin's-head in size, of complicated structure, its external layer consisting of spicules of singular form, like a pair of wheels on an axle in miniature. The axle lies radiately in the wall. The spot where no shell is formed remains as an aperture, through which in spring, the amœbiform contents creep out from their winter quarters, and soon develop into the young Sponge.

The various members of the sub-family Spongillina do not differ except in trifling details from *Spongilla*; though they have not yet been described from Australia, they are otherwise of world-wide distribution, and from this we may infer that they are a group of great antiquity. Owing to the rarity of fresh-water fossils, and the exceptional preservation of Sponge remains, it is not to be expected that we should find direct evidence of this, and it is, therefore, all the more satisfactory that traces of *Spongilla* have been found so far back as the Purbeck strata, where its chief spicules have lately been detected in fresh-water chert.

Spongilla is so similar in many respects to *Amorphina*, which sometimes lives in brackish water, that it is very possibly derived from it. It is a singular fact that of the many hundreds of widely different kinds of Sponge, none but a small rigidly-defined group should be found inhabiting inland waters. This is probably due not to the inability of Sponges to adapt themselves to fresh water, but rather to the fact that they are propagated by ciliated larvæ, which drift about at the mercy of

* After the naturalist Renier.

every current, and cannot, therefore, ascend a river where the current is always seaward. This explanation will probably account for the absence of many other marine forms of life which one might expect to find amongst the fauna of our rivers.

The statoblast is no doubt an adaptation to preserve the Sponge from the extreme climatal changes to which fresh water is exposed; thus in Bombay it develops at the time of summer droughts, in temperate climates on the approach of winter. It is worth noticing that the statoblast of the Polyzoa also occurs only in the fluviatile forms.

*Suberitidinæ.**—In these Sponges the spicules are characteristically pin-shaped, densely aggregated together, either in fibres, or matted felt-like. The surface often bristles with the projecting points of radiating spicules (Plate 71, Figs. K, L), but is never provided with a regular spiculous network like that which usually occurs in the Renierinæ.

The large Sponge appropriately named Neptune's Cup (*Poterion Neptuni*,† Fig. 9, C), found growing on the coral reefs of the Indian Ocean, and fossil in the English chalk, is a Suberite. A near relation, possessing the same pin-like form of spicule, is the little burrowing Sponge *Cliona*, which eats its way into shells, particularly oyster-shells. Shells so infested may often be seen at the fishmonger's. They may be at once distinguished by the numerous round holes which cover the surface. The holes are of two sizes, the larger for the emission of oscular tubes, the smaller, which are much more numerous, for poriferous tubes. On splitting the shell open both are found to communicate with irregularly swollen canals, which are occupied by the yellowish-coloured body of the Sponge. If the oyster, fresh from the sea, be placed in a vessel of cool clear sea-water, a beautiful sight will soon present itself. From the various apertures delicate mobile tubes protrude. Those from the larger end in a single oscular opening; those from the smaller expand at the end into a conical form, resembling, with the swollen base perforated by numerous little pores, the "rose" of a watering-pot, with the addition that here the margin of the "rose" is fringed with a corona of delicate diverging spicules. The tubes are very sensitive not only to touch, but to the incidence of light, instantly contracting and withdrawing themselves when exposed to powerful sunlight. Currents of water flow into the poriferous tubes, which swing to and fro, seeking the water most to their taste, and from the equally mobile oscular tubes currents briskly escape. In autumn, this sponge-mass will be found crowded with little oval yellowish bodies, about $\frac{1}{20}$th of an inch long, which are the ciliated embryos or larvæ of the Sponge. Spicules are already developed in them. The burrows of Cliona occur in fossil shells of the Silurian strata.

Desmacidinæ.—This is the culminating group of the Monaxonidæ, distinguished by the rich variety of its spicule forms. Besides the chief spicules, which are usually bi-radiate (acerate or acuate), there are always present one or more forms of small spicules, C and S-shaped hamates; tri-curvates; equi- and inequi-anchorates, singly dispersed or clustered into rosettes; and trichite-sheaves. It is from this group that the Tetractinellidæ have probably been derived.

Echinonemata.‡—The skeleton is characterised by Carter as composed of chief spicules lying parallel to form a fibre, which is spined by other (echinating) spicules projecting from it. Schmidt considers the absence of hamates and anchors essential to the definition of the Chalinopsidinæ, a group otherwise equivalent to the Echinonemata. Spongin is usually present, cementing the spicules together; it may increase in quantity, replacing the spicules, which may diminish to a single row, or disappear from the interior, the echinating forms of course persisting. Should they also vanish, the Sponge would become a Cerospongia.

Chalinidæ.—The common *Chalina occulata* of the British coasts is a good example of this group. The skeleton consists of spongin fibre, cored by silicious spicules, which are usually monaxial; echinating spicules are absent. The relative development of the spicular axis and the spongin wall is very variable, some, like *Pachychalina*, approaching the Renierinæ by the preponderance of spicules; others, like *Chalina*, approaching the true horny Sponges (Cerospongia) by the excessive development of spongin. This family, indeed, links together the Silicispongiæ and the Cerospongiæ, and since its spicules must apparently be formed before the spongin which envelops them, it would appear rather that the Cerospongiæ were derived from the Silicispongiæ by loss of spicules, rather than the latter from the former by their acquisition.

* Latin, *suber*, cork. † Greek, *poter*, a drinking cup. ‡ Greek, *echinos*, a hedgehog; *nema*, a thread.

The Monaxonidæ are cosmopolitan, chiefly shallow-water forms. They range from the strand-line down to 862 fathoms; on the evidence of Cliona borings in Silurian fossils they are concluded to have been in existence in early Palæozoic times; fossil remains of their skeletons are rare, *Pharetrospongia Strahani* (Sollas) of the Cambridge greensand, a large Renierine Sponge with a fibrous skeleton, being the best preserved and most certainly demonstrated example yet known.

*Tetractinellidæ.**—This sub-order embraces two very different groups; the *Choristidæ*, in which the spicules are separate from each other, and the *Lithistidæ*, in which they are united by the interlocking of their branched ends into a dense stony network.

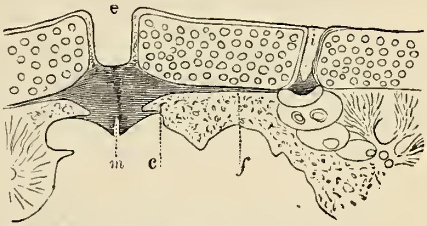


Fig. 15.—SECTION THROUGH THE RIND OF A GEODINE SPONGE. (*After Sollas.*)
c, gelatinous connective tissue; e, excurrent canal, closed by the muscle (m); f, fibrous tissue; i, incurrent canal.

In the *Choristidæ*† are united a number of very different types of Sponges, of which the Geodina are best known. In these the body, usually more or less spherical, is differenced into an external rind and an inner mark, or parenchyma, like an orange; the rind (Fig. 15) consists of a layer of fibrous connective tissue, covered externally by the ectoderm and a layer of minute flesh-spicules; its outer two-thirds is crammed full of spicules, usually trichite-globules (mistaken by Bowerbank for ova), which give to it great firmness and consistency. The incurrent canals in their passage through the rind present a very definite, usually hour-glass form, the constricted part being defended by a sphinctral muscle, produced by a modification in the character of the surrounding fibrous layer. The chief spicules are large acerates, which lie in bundles or fibres radiating towards the surface, near which some of them divide into three rays, forming forks and anchors.

The *Lithistidæ.*‡—Notwithstanding the firmness of their coral-like skeleton these are no more characterised by constancy of form than the other groups of Sponges; they usually affect cup-like, lamellar, top-shaped, or cylindrical forms, are occasionally branched bush-like; generally attached, sometimes by a longer or shorter stalk, which branches out root-like below. Their skeleton consists of the united body-spicules (Fig. 10, *k*); of surface spicules, anchor- or fork-shaped, or disciform; and minute so-called flesh-spicules. Differences in the character of the body-spicule have afforded Zittel a means of dividing this group into four families, in one of which, the *Megamorina*, the quadri-radiate form of the body-spicule is nearly lost, and the central canal or axial-thread has a simple uniaxial form (Fig. 10, *m*).

The Lithistidæ occur in the Atlantic, Pacific, and Indian oceans; they are essentially deep-sea dwellers, ranging from 74 to 805 fathoms. By reason of the comparatively large size of their body-spicules, and the union of these into a stout resistent framework, they stand a much better chance of fossilisation than the Monaxonidæ; they are accordingly by no means rare in a fossil state, and have been found in most marine formations from the Upper Cambrian to the Tertiary. The well-known *Siphonia* of the Blackdown greensand is a familiar instance (Fig. 9, D).

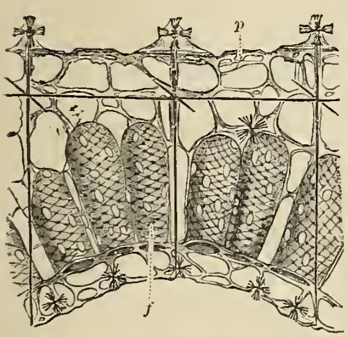


Fig. 16.—SECTION THROUGH THE WALL OF EUPLECTELLA (× 75). (*After Schulze.*)
p, pores; f, flagellated chambers.

Hexactinellidæ.—These Sponges are clearly defined from all other Silicispongiæ by the sex-radiate form of their spicules, and by the characters of their soft tissues so far as these are known. The chief spicules are either loosely arranged into a fibrous skeleton (Lyssakina, Fig. 17, A) or cemented into a solid network by a deposit of silica (Dictyonina, Fig. 17, B), in which they are as completely enveloped as the spicules of *Chalina* in spongin. A slight deposit of silica may unite together the spicules of some Lyssakina, *e.g.*, Euplectella, but never to the extent of completely enveloping them.

The *Lyssakina*§ include such forms as *Holtenia*, a somewhat cylindrical Sponge, with a large

* Greek, *tetra*, contr. of *tettara*, four; *actis*, a ray. † Greek, *choris*, separately.
‡ Greek, *lithos*, stone. § Greek, *lysis*, loosing.

central oscular tube fringed by whisker-like spicules, and a thick beard-like growth of anchoring spicules, which serve to support it in the soft slimy ooze of the deep sea in which it lives; *Hyalonema** (Fig. 9, B), the Japanese glass-rope Sponge, a close ally of *Holtenia*, but at once distinguishable from it by the spiral wisp or rope into which its anchoring spicules are twisted together; the upper end of the rope is overgrown with encrusting Palythoa, the lower end frays out by the divergence of the spicules; deprived of the Sponge the rope may often be seen in private houses stuck topsy-turvey under a glass-shade; an instance of the perverted ingenuity of the Japanese divers by whom it is obtained and "prepared."

Euplectella† (Fig. 9, A), with a framework so exquisitely beautiful in its fairy-like tracery as to have called forth the remark from a distinguished naturalist "this passes the love of woman," has now also become an ornament to glass-shades; it is a Lyssakine, with spicules so arranged crossing one another as to weave together a thin-walled vase of delicate lattice-work with square meshes. In the fresh state, when the skeleton is imbedded in the mesoderm, over every alternate mesh, a conical process of the Sponge-wall projects, the other meshes open by a round hole into the interior of the vase. Beneath the poriferous skin (Fig. 16), which is adorned with flesh-spicules, and supported on the distal rays of sex-radiates, thin threads of mesoderm form an irregular network, in which the flagellated chambers are immersed. These are cylindrical sacs, open at one end, closed and hemispherical at the other; each is perforated by several pores, through which water can enter from the surrounding lacunar spaces of the mesoderm; by their open ends they communicate with the digitately branched excurrent canals, which freely open into the central cavity of the vase. The water, which streams successively through the skin, the flagellated chambers, and excurrent canals into this cavity, escapes partly by the open meshes in the side of the vase, and partly through a netted lid which closes its end. Like so many of the Hexactinellidæ which live in the mud of the deep sea, Euplectella terminates below in a tuft of anchoring spicules; but when it is found in shallower water on a hard bottom it becomes attached, and its anchoring spicules abort.

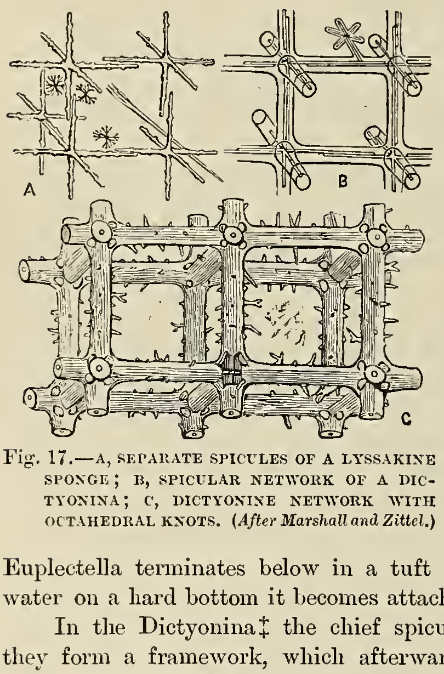


Fig. 17.—A, SEPARATE SPICULES OF A LYSSAKINE SPONGE; B, SPICULAR NETWORK OF A DICTYONINA; C, DICTYONINE NETWORK WITH OCTAHEDRAL KNOTS. (*After Marshall and Zittel.*)

In the Dictyonina‡ the chief spicules are so disposed that by the overlapping of their rays they form a framework, which afterwards being overrun by silica becomes a continuous net; the knots or nodes of this net correspond generally with the centre of the spicules, its connecting fibres with two overlapping rays (Fig. 17, B). The spicules are not always so regularly arranged as in the figure; and in many genera they depart widely from a three-axed form, the rays diverging at all angles, so that one fibre may contain more than two and as many as all six rays. Loose sex-radiate spicules are always associated with the network, and delicate minute or flesh spicules are general throughout the Sponge. The "flower-basket" sponge *Dactylocalyx* (Fig. 9, E), the earliest discovered instance of a Hexactinellid, is a good example of this group, and *Farrea* is another, distinguished by the regularity of its square meshes. In some Dictyonina the investing silica fails to completely fill the angles at the centre of the spicules, but stretches across in fine threads from one ray to another, sketching out the edges of a regular octahedron, with the spicular rays for its axes. This structure was accurately described long before it was understood, by Toulmin Smith, who showed that it characterised the network of the Ventriculites. It is only quite recently that an existing Sponge has been described (*Myliusia*) in which the same structure prevails (Fig. 17, C).

The Hexactinellidæ inhabit all seas, and are found in deep water, ranging from 98 to 1,591 fathoms, and probably more. They make their appearance in time very early, remains of a Lyssakina (*Protospongia*) being found in the Lower Cambrian rocks at St. David's, South Wales; both Dictyonina and Lyssakina occur in the Silurian of North America; in the Carboniferous

* Greek, *hyalos*, glass. † Greek, *eu*, well; *plectos*, woven. ‡ Greek, *dictyon*, a net.

of Scotland, a genus, *Acanthospongia*, closely allied to *Hyalonema*, has been described by Professor Young, of Glasgow, and later by Mr. Carter. In the Jurassic strata Hexactinellids are well represented, and in the chalk they abound, the graceful and varied Ventriculites being well known to collectors in the Downs of Sussex.

CEROSPONGIA.

This order consists of Sponges with a spongin skeleton, but without proper spicules. The axis of the spongin fibre may be occupied by soft organic matter only (*Ceratina*), or it may involve various foreign bodies (*Psammo nemata*) [Greek, *psammos*, sand]. The Bath Sponge, already fully described, is a member of the Psammonemata. *Luffaria*, of which an illustration is given in Plate 71, belongs to the Ceratina. No examples of these widely-distributed sponges are yet known in the fossil state.

The literature of the Sponges is copious, but much of it very inconveniently scattered in separate memoirs through journals and magazines. For general information, and descriptions of species, may be quoted Oscar Schmidt's volumes on the Sponges of the Coast of Algiers, of the Atlantic Ocean, and of the Gulf of Mexico; Haeckel, Die Kalkschwamme; numerous papers by Carter in the "Annals and Magazine of Natural History," where also papers by Sollas appear; for masterly accounts of structure and embryology see F. E. Schulze in several numbers of the "Zeitschrift für Wissenschaftliche Zoologie," where also are papers by Metschnikoff and Oscar Schmidt. A history of the Sponges will be found in George Johnston's "British Sponges," and good descriptions of British species in Bowerbank's "Monograph on the British Sponges," 3 vols. Jules Barrois has published "Researches on the Embryology." For fossil Sponges see the fine works of Zittel, and papers by Sollas in the *Quarterly Journal of the Geological Society.*

W. J. Sollas.

THE RHIZOPODA.

The Rhizopods—Appearance—Protoplasm or Sarcode—Its Character and Functions—The "Contractile Vesicle"—*Amœba* and *Monera*—True "Cells"—Assimilation of Food—Contents of the Endosarc—The "Vacuoles"—Food of the *Amœba*—Naked Lobose Rhizopods—Shelled Lobose Rhizopods—Sun-animalcules—*Actinophrys sol*—The Radiolaria—The Polycistina—The Reticularia—The Foraminifera—Imperforate or Porcellanous Foraminifera—Perforate or Vitreous "Forams"—The Flagellata—Gregarinæ—The Link Connecting the Rhizopods and Vertebrates—Bibliography—Classification.

I. Among the minute animals which escape our naked sight, but may be seen by the aid of a magnifying glass in some instances, but often only under the far stronger lenses of the microscope, are those which are known as Rhizopoda,* or *Myxopoda*.†

They have, in a great degree, the same simple constitution as several other kinds of animalcules which are grouped by naturalists as *Protozoa*,‡ such as *Infusoria*§ (also Sponges), their essential living material being merely a structureless and jelly-like or mucous substance; and thus they stand as the *first* in the scale of animal organisation, as it rises from the most simple to the more highly organised animals with their manifold tissues and complicated structures.

II. The delicate albuminous material of the Rhizopods and their allies is a "semi-fluid, nitrogenous, formative substance," termed "Protoplasm,"‖ as being the simplest or *first* life-matter known to us. It is also called "Sarcode,"¶ as supplying the place of flesh, rather than being flesh-like itself. It is probably composed of carbon, hydrogen, oxygen, and nitrogen, like some other organic compounds; and it is the physical basis of life in both animals and vegetables.

This slimy, white-of-egg-like sarcode of the Rhizopods, though granular, with exceedingly fine particles, and to some extent differentiated by local formation of special groups of granules, known by some as "Endoplasts,"** shows no definite parts or divisions of a body such as characterise higher animals; nor has it permanent limbs, nor body-cavity, nor alimentary canal, nor nerves, nor blood. Nevertheless, it serves for and fulfils all the necessary actions and processes of life.

Its outer portion is generally distinguishable from the interior, and is sometimes toughened into a kind of membrane, or hardened with mineral matter into a shelly coat, or a stiff skeleton of network.

More especially this corpuscle of sarcode has in itself a particular kind of motive plasticity, whereby it can advance with a slowly-flowing movement of all or a part of its substance. In the latter case, the elongated portions, whether thick or thin, are termed "Pseudopodia."††

The constituent atoms or granules, moreover, in their glairy slime, are mutually, if not equally, engaged in the functions of movement and of assimilation of nutriment, and in the multiplication or reproduction of individuals. In the active animal they seem to flow in a kind of circulation through the little mass, and along the protruded lobes or threads; and in many cases form special aggregations of granules, or endoplasts. The smaller of these are termed "Sarcoblasts,"‡‡ and may be regarded as ovules, or little eggs, formed within the parent, and when free, by escape or by emission, becoming new little beings like the parent. A larger endoplast constitutes the "Nucleus," in the middle of the animalcule. This internal corpuscle seems to be essential to the economy of most of the *Protozoa*, forming, as it were, a starting-point of one kind of germination; and it is the first representative of a permanent vital organ.

Another prototype or forerunner of more highly constituted organs is a minute bladder-like collection of clear fluid, which in some part or other of the body, but generally towards the hinder end, is seen to increase slowly to fulness; then, suddenly contracting, to collapse and become empty, at almost regular intervals of time. This "Contractile Vesicle" seems to be analogous to, if not really, an organ of secretion and distribution.

* Greek, *rhiza*, a root; *pous*, a foot.
† Greek, *myxa*, mucus; *pous*, a foot.
‡ Greek, *prōtos*, first; *zoön*, an animal.
§ So called from having been first found in infusions of hay and other vegetable matters. But many of the little creatures first grouped under the name have been separated off, and the *Infusoria* are special protozoan animalcules.
‖ Greek, *prōtos*, first; *plasma*, a formation, from *plasso*, I shape or mould.
¶ Greek, *sarx*, flesh; *eidos*, form or appearance.
** Greek, *endon*, within; *plastos*, formed or moulded.
†† Greek, *pseudos*, false; *pous* (*podos*), a foot.
‡‡ Greek, *sarx*, flesh; *blastos*, a germ.

III. The above-mentioned characters may be readily observed in one of the most common forms of Rhizopods, namely, the *Amœba,** or proteus-animalcule, so called on account of the ever-changing shapes which a well-conditioned active individual puts on while moving under the microscrope, and pushing out and drawing in the various projections on its surface, sometimes like fingers or threads, called pseudopods.

There are, however, certain living atoms of protoplasm so simple in condition, being quite structureless, except in having constituent granules, that some naturalists have separated them from the *Amœbæ* and the other *Rhizopoda* in classification, and called them *Monera*;† not so much in view of their singleness, as on account of their *unity* of composition. They may, however, be *intermediate* forms, or passages from one stage to another in the growth and development of certain animalcules. Some of them may even be the germ-products of low plant-structures.

Some appear to be so destitute of any structural features that their slime-body shows no distinction between the outer and inner parts, and has no nucleus; and their free, homogeneous, jelly-like substance, in moving, stretches itself out in one direction or another in lobular, finger-like, or filamentous prolongations, and contracts again, either over such organic atoms as seem to be its food, or towards a point where such a protruded part has adhered and fixed itself.

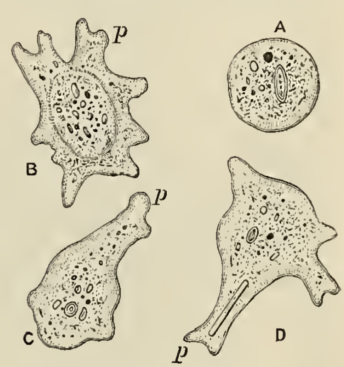


Fig. 1.—AMŒBA PROTEUS.

A, in the contracted or "encysted" state; B, C, D, in motion; *p*, *p*, *p*, pseudopods pushed out in action. Highly magnified.

Some such amœboid creatures are shown in Fig. 1; and their elementary simplicity has originated for one kind the name of *Protamœba*,‡ and for another, *Protogenes*.§ The latter is a relatively large and outspread mass (three or four millimètres in diameter) of such protoplasm as is known as a "plasmodium."‖ This is similar to the protoplasm of the much smaller *Protamœba* (scarcely $\frac{1}{20}$th of a millimètre in width), but is made up of a combination of many such individuals.

Reproduction of the species is carried on either by the separation of individuals from the parent mass, by their splitting off, or by the parent dividing into two.

Other *Monera* begin life like the *Protamœba*, but after a while they cease to be active, becoming quite still, and enter on what is known as the "resting-stage" in *Infusoria*, the *Amœbæ*, and other animalcules. In this quiescent state they are round, and become enclosed in a tough coat, and are said to be "encysted,"¶ until before long the enclosed morsel of protoplasm resolves itself into numerous definite minute bodies, each capable of living by itself when set free, and hence termed "Zoöspores."** Sometimes these tiny corpuscles, combining together, form a new gelatinous mass (plasmodium), like that of the parent, as in *Protomyxa*†† and some other relatively large Moneres, not nucleated in every stage of their growth, creeping by means of their soft mobile body at first, and afterwards by the contractile filaments of their sarcode, which branch out and form delicate reticulations, with irregular meshes, as in some *Rhizopoda*. As these animalcules, closely as they may be related to the Rhizopods, differ from them somewhat in their mode of growth, and in their changes from one stage to another, they have been grouped in some classifications under other distinctive names, such as *Myxomyceta*,‡‡ *Myxogastrea*,§§ and *Mycetozoa*.‖‖ It is difficult for botanists to regard them as belonging to the animal kingdom.

IV. The above-mentioned lowly creatures of the *Amœba* and *Protamœba* types show a close analogy to the elementary "cell," which, in some condition or other, is known to be at the foundation or commencement of all kinds of animal and vegetable tissues. A "cell" consists of a minute sac, or bladder-like envelope (the "cell-wall"), and an enclosed morsel of fluid or semi-fluid gelatinous

* Greek, *amoibè* (*ameibo*) exchange.
† Greek, *monos*, alone.
‡ Greek, *prōtos*, first; *amœba*.
§ Greek, *prōtos*, first; *geinomai*, I am born.
‖ Greek, *plasma*, a formation; *eidos*, appearance.
¶ Greek, *en*, in; *kustis*, a bladder.
** Greek, *zoë*, life; *sporos*, a seed.
†† Greek, *prōtos*, first; *myxa*, mucus.
‡‡ Greek, *myxa*, mucus; *myces* (gen. *mycetos*), a fungus.
§§ Greek, *myxa*; *gastre*, the bottom of a vase, or the hold of a ship.
‖‖ Greek, *myces*, a fungus; *zoön*, an animal.

protoplasm (with its innumerable floating molecules, granules, or globules), possibly a network of filaments, and a more or less solid "nucleus"; and this last has often within it an almost immeasurably small but distinct spot called the "nucleolus." Such "cells," being endowed with vital force, can absorb and use up water and organic fluids; they have the power of growth, of secreting new materials, of producing similar "cells," capable of the same functions as those of the parent "cell" (and even more advanced functions); and in many cases they can move freely. The "nucleus," secreted or formed by the protoplasm, seems to regulate these vital phenomena, especially germination or reproduction, for it multiplies itself by "fission," by breaking up into germinative particles, and by the formation of "nucleoli," which, in their turn, become "nuclei."

Even without a "cell-wall," the *Amœba* is a true animal "cell"; but the *Protamœba*, having neither "cell-wall" nor "nucleus," represents only the simple protoplasm of a "cell." Such living corpuscles have been termed "Protoplasts" by some, and "Cytodes"* by others. Such are the free-moving *Monera* (*Protamœba*), the non-nucleated plasmodia of the *Myxomyceta*, and the amœboid germs of *Gregarina*, proceeding from the "pseudo-naviculæ." That all these simple organisms, however, are true animals has not yet been satisfactorily determined.

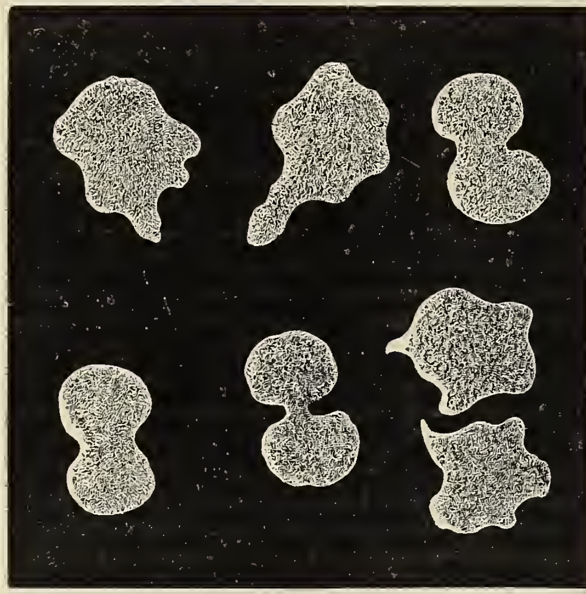


Fig. 2.—PROTAMŒBA PRIMITIVA.

Showing some of the stages during the process of fission. Very highly magnified. (*After Haeckel.*)

"The *Amœba*, however," says Haeckel, "presents the most simple form of a single-celled ('unicellular') organism in a complete state of development, and in some sort the ideal of an animal 'cell.' Widely distributed in fresh waters, on muds and wet earth, and occurring in brackish and salt water also, these animalcules are of special interest on account of their eminently simple structure as a 'cell,' and because of the bearings of their development and functions on the history and meaning of other 'cells.'"

V. Thus the *Amœbæ* may be said to be soft, naked, nucleated "cells," of indeterminable shape. They move here and there in water, sometimes floating, but usually creeping on plants and other objects by protruding from any part of the surface of their body, but more especially from one end, and that the broadest and most translucent, variable finger-like lobes of their own body-substance, and then either retracting these processes, called "pseudopods," or drawing the body to the point at which they fix themselves. Of course the body varies indefinitely throughout these movements (*see* Figs. 1, 2, 3), being at one time nearly circular, at another angular, and then jutting out at corners or at the sides with capes and peninsulas of no fixed shape, and ever slowly shifting, as if a floating island, restless and bewitched, gained and lost its coasts again and again at the caprice of some changeful sprite, aiming at fancied resemblances to hands, antlers, or branches, and back again to more solid but clumsy shapes of leaves and buds, and even slugs or imperfect stars.

"The changes of form produced by the extension and branching of certain of the pseudopods, with the recession, melting away, and total disappearance of others, is endless. Sometimes the animal creeps onward in a flowing manner with comparatively simple cylindroid form, occasionally emitting a single pseudopod on one side or the other. More commonly in movement it assumes a dendroid or palmate appearance, or sometimes, diverging from the directly onward course, it becomes more radiate. Not infrequently it assumes more or less grotesque shapes, in which almost every conceivable likeness may be imagined."—Leidy, "Freshwater Rhizop. N. America," 1879, p. 36.

* Greek, *cytos* (plural *cyta*), a hollow; *eidos*, appearance.

Organic morsels over which these *Amœbæ* softly glide are taken into the plastic body, sometimes at any spot, but generally at a particular region, where the clear sarcode is thinnest; and water is also absorbed or enclosed. Thus the acts of eating and drinking, without mouth and stomach, are accomplished; and assimilation (rather than digestion) of the good and available portions of the prey duly takes place.

After continued growth, the body sometimes divides into two living individuals; but it often becomes almost wholly a mass of zoospores, so that the once unicellular creature is converted into an uncountable multitude of living "cells" or simple animals.

Thus also the "cells" in our own bodies play their part; multiplying new "cells," and replacing those which have been used up. More especially the white globules of the blood of animals are amœboid. As they circulate along the vessels, they execute movements like those of *Amœbæ*, ever modifying their shape; and they can be made to enclose foreign substances (such as carmine), just as the *Amœba* takes in its food. Further, a simple *Amœba* has a striking resemblance to the "primary cell" or "ovum" of all animals, whether vertebrate or invertebrate. It may be regarded as equivalent to this unicellular phase of higher organisms. As a vital mass of the simplest and most elementary formation we can conceive, it is adapted for a very low stage of existence, having only the properties of locomotion, assimilation, and reproduction. Having such an extremely rudimentary formation, many of the *Protozoa* have been regarded as members of the Vegetable Kingdom, and as mere germs of some plants. Haeckel places many of them, as *Protista*, in an intermediate position. The *Amœba*, however, and its numerous allies, prey on organic substances, and even on living organisms, after the manner of animals. But in this great group they take their place, in classification, according to the relative absence of those special organs which characterise the higher members of the kingdom.

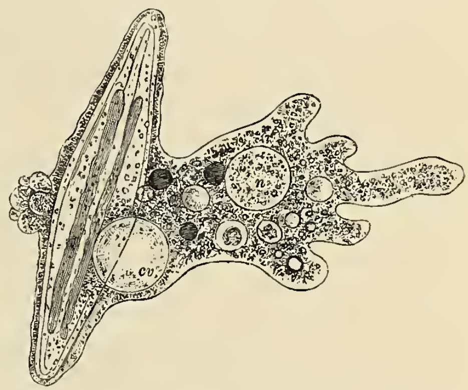


Fig. 3.—AMŒBA PROTEUS, WITH PSEUDOPODIA ADVANCED TO THE RIGHT, AND A LARGE *NAVICULA* ENVELOPED IN THE DISTENDED HINDER PART. THE PAPILLARY OR MULBERRY-LIKE EXTREMITY IS SEEN TO THE LEFT OF THIS.

n, Nucleus; *cv*, contractile vesicle; the dark spots are food balls and food vacuoles. Magnified 500 diameters. (*After Leidy.*)

VI.—The sarcode of the *Amœba* is often yellowish from its contained granules; but it is nearly transparent at one, usually the broader, end of the body in active individuals; whilst the granules, germinal and other globules, and particles of food, more or less digested, with green, yellow, brown and other tints, crowd and darken its hinder part. The edge of this, under the microscope, looks like a pellucid coat (in section) by transmitted light; and being free from coarse particles, invests, as it were, the thicker interior with a thin layer of sarcode. The more coarsely granular and inner material is called the "Endosarc;"* the other is the "Ectosarc,"† or "Diaphane."‡ They are really interchangeable; the outer surface, which is toughish, without being coated with any membrane, may be turned in and become sa ssoft as the rest of the sarcode, especially when the prey is engulfed and takes in some of the inturned ectosarc with it.

The contents of the endosarc appear to be:—1. Granules of various kinds—some exceedingly minute and protoplasmic, others relatively large, some of which are apparently like water, some like oil, some like starch; 2. Newly ingested food—some soft (Desmids, &c.), some hard (Diatoms)—and food-balls of partly digested food, which soon become broken up as loose particles in the endosarc; 3. Water-vacuoles, either independent or investing morsels of food, and probably arising from water engulfed either by itself or with the food; 4. Quartz sand sometimes, and "in some fine, large, vigorous specimens of *A. proteus*, collected from a pond in the vicinity of a saw-mill," Dr. Leidy found that "the endosarc contained multitudes of particles of sawdust;" 5. Minute crystals, regular in form (octahedrons and others); 6. Sarcoblasts; 7. The nucleus; and, 8, the pulsating or contractile vesicle. There may be more than one of each of these.

* Greek, *endon*, within; *sarx*, flesh. † Greek, *ektos*, outside; *sarx*. ‡ Greek, *diaphanes*, transparent.

The wider, often fingered, and always forward-moving, clear part of the body has been observed to be not so viscid and sticky as the narrower, coarse-grained, food-carrying hinder portion; and the food has been seen to be taken in by the creeping mass, as it flows on like moving slime, more frequently just about the place where the clear passes into the granular part, than at other parts of the body. Yet even one or more of the pseudopods can take prey by enwrapping it and passing it on to the interior.

All the granules, whether of partly digested food, or germinative spherules, or protoplasmic atoms, are often seen to stream forward along the middle of the animalcule, encroaching sometimes on its clear moiety, and then to return down each side, to be swept forward again, with varying energy, in a kind of circulation or "cyclosis."* But this is associated with the movement of the animal, and is not analogous to a systematic blood-circulation.

The process of digestion or assimilation is as yet a mystery of organic chemistry. The refuse of the food is gradually accumulated in small lots towards the hinder end, and is let out now and then through the clear sarcode of the surface. Germinal granules or zoospores sometimes escape at these opportunities.

When a lobe or pseudopod is pushed out, the miscellaneous particles of the endosarc appear to rush toward the new projection; but for the most part only the sarcodic granules follow it up and continue the "cyclosis" in its substance.

The protrusion of a pseudopod is often preceded by an energetic contraction of the pulsating vesicule, and it has been remarked that, though there is no apparent opening in the common *Amœba* for the contents of this vesicle to escape outwardly, it is always at or near the surface of the hinder end when emptying itself. In some cases it may force its fluid far among the atoms of the protoplasm, whether as nutritive or excretory matter. It acts best when the animalcule is in good condition; and then it is that the movements of pseudopods or other superficial parts are seen to follow its contraction. In a large *Amœba* with a villose patch at its end, Dr. Wallich thinks it probable that each ruptured vesicle leaves a ragged edge, which hardens too soon for it to be wholly absorbed into the general sarcode, and thus leaves outstanding morsels (villi) of permanently indurated ectosarc.

There are also visible in the *Amœba* one or more of the clear spots already referred to, which do not fill and collapse at regular intervals. These are known as "vacuoles."† Some are "water-spaces," and seem to be relatively persistent; others are formed temporarily round large particles of food. The following lucid description of such a "food-vacuole," from the pen of Prof. P. Martin Duncan, is especially apt:

"A large *Amœba* with a very delicate endosarc had been feeding on broken-down Conferveæ, spores, and green cells, when a tolerably large Diatom, a *Pinnularia*, came in contact with its small end. The scanty diaphane then immediately increased in quantity and flowed over the intruder, which sank, as it were, gradually into the endosarc, and remained in one part of it. After a few minutes had elapsed, a clear space formed in the *Amœba* around the prey, which immediately began to move in it backwards and forwards after its usual fashion. The space was evidently filled with water, and therein moved the captured Diatom, apparently in no great discomfort. After long watching, it became apparent that the size of the space, or *vacuole*, as it is termed, increased, and that the Diatom became stationary and ragged-looking, and, in the course of more than a day, it split and separated into two halves. After this the vacuole disappeared, and the relics of the meal were jumbled up in the group of granules and other digested bits which streamed about in the endosarc."‡

Dr. Leidy observes that the food of the *Amœba* commonly consists of "various Diatoms, Desmids, green unicellar Algæ, and spores of the filamentous Algæ. Considerable fragments of the latter, such as Oscillaria, Zygnema, &c., are also often seen among the food contents. Occasionally animal forms may be detected in the food materials in the endosarc, among the most common of which are the Rotifers; and in several instances I have observed with them an unfortunate Arcella, a Difflugia or a Trinema." Dr. Leidy also describes and

* Greek, *cyclos*, a circle.
† Latin, *vacuus*, empty; hence a "diminutive," vacuolum.
‡ "Popular Science Review," new series, vol. i. p. 232.

figures the capture, swallowing, and digestion of an *Amœba verrucosa* by a cannibal (*A. proteus*). Elsewhere Dr. Leidy gives an account of another capture:—"In one instance I saw an individual (*A. proteus*) containing, within a large vacuole, an active Infusorian (a *Urocentrum*), and having a second victim of the same kind included in the fork of a pair of pseudopods, the ends of which were brought into contact, so as to imprison the animalcule within a circle. The latter moved restlessly about within its prison, but after a time became motionless, and shortly after the ends of the pseudopods which enclosed it fused together. . . . . Fibres of ectosarc extended from the body of the *Amœba* towards the fused ends of the pseudopods, and finally the *Urocentrum* was enclosed in a vacuole like that in the interior of the body of the *Amœba*. Having carefully watched the latter for some time, the two vacuoles containing the captured *Urocentrums* were seen gradually to diminish in size, the contents were reduced to the usual size of the ordinary food-balls of the endosarc, and all trace of the previous character of the victims was completely lost." Dr. Leidy adds that "the different food-materials undergo chemical changes as a result of digestion in the endosarc, and colours become changed in a striking manner. The bright green chlorophyll of Algæ becomes brown or yellow, and shrivelled within the colourless cells; and the endochrome of Diatoms becomes browner in tint, and shrivelled into two narrow strings within each shell."

Dr. Wallich has watched the process of a *Furcularia* eating pieces out of an *Amœba;* but he has also seen this Rotifer a prey to an *Amœba*.

VII.—In the foregoing remarks on the *Rhizopoda*, we have alluded to one of the simplest (*Protamœba*, Fig. 2), and to one of the most highly developed (*Amœba*, Figs. 1, 3), for the convenience of describing both the general and the essential characters of the sarcodic elements belonging to the whole group. In entering on a description of the other special forms, it would be technically correct to begin with the simplest and to proceed to the more advanced. But, in the first place, it is best for general observers to have some notion of that Rhizopod (*Amœba*) most commonly met with. Secondly, the order of any natural group is little like a straight line, but far more resembles a network, or a reticulate series of rings touching each other, on account of passages and gradations among characters, features, and structures not essential to strict zoological distinction, but analogies only, or homologies, nevertheless striking and useful to the student in remembering tabulated arrangements. Thirdly, whilst internal organs cannot always be readily seen, the external visible character of shelled or shell-less, of skeleton or no skeleton, of long or short, thick or thin pseudopods, of creeping, swimming, or stationary habits, at once takes the attention of the amateur, and serves to direct him to the right family and order.

Several classifications have been suggested, mainly on the difference of general shape and of pseudopodial elongations, on the variations of ectosarcal consistency, and difference of tests and skeletal supports. These plans have been noted and reviewed by Wallich, Leidy, Claus, and others. Dr. Wallich, however, has pointed out the grounds on which a really natural classification of the *Rhizopoda* should be founded, namely, on the absence or presence of what appear to be specially differentiated parts of the sarcode, such as the *nucleus* and the *contractile vesicle*. These structures, elementary as they are, he believes to be indications of progressive organisation, and, as such, to afford a good structural and physiological basis for grouping the allied creatures in zoological order. Thus, first, those which have neither a definite nucleus nor a contractile vesicle he terms *Herpnemata* (creep-threads), such as the *Foraminifera* (hole-bearers), with calcareous shell, and the *Polycistina* (many baskets), with silicious skeleton; secondly, those which have a definite nucleus, but no contractile vesicle, are his *Protodermata* (first-skins), of which some have their skeleton of solid silicious spicules and rays (*Plagiacanthidæ*, *Acanthometrina*, *Thalassicollina*), and others have a silicious skeleton of tubular fibres (*Dictyochidæ*); thirdly, those Rhizopods which possess both the organs mentioned above form the highest group, viz., the *Proteina* (Proteus-like). These are divisible by their pseudopods being either (1) "monomorphous" (single-shape), or (2) "polymorphous" (many-shape). The former division are the *Actinophryna;* the latter are the *Amœbina*.

For the reasons above stated, using the word "Rhizopoda" for the whole group, we will take them in order, from the *Amœba* downwards, with little violence to Dr. Wallich's system, though

reversing it, through those most highly organised, with nucleus and special vesicle, to those that appear to have only a nucleus, and then to such as have neither.

Professor Schulze and Dr. Hertwig believe that they have discovered a nucleus in *Foraminifera;* and some of their examples, at first sight, are very striking. The presence, however, of other endoplasts in recent specimens, and the possible artificial production of nuclear bodies in sarcode by re-agents, still keep our doubts alive; and Dr. Wallich is not yet inclined to alter his views as conveyed in the foregoing sketch of his system.

VIII.—Beginning with *Amœba*, essentially the best-organised of the Rhizopods, we have *A. proteus* (Figs. 1, 3). Its name was founded on Linné's catalogue of organic beings in the later editions of his "Systema Naturæ," and on the still earlier appellation of "the little Proteus,"* given by Rösel, in 1755, to this animalcule long before its real nature was understood. It is also known as *princeps*, having this name in Ehrenberg's magnificent work on *Infusoria*, &c. It was referred to as *Proteus diffluens* by Müller in 1786; and this would have been an appropriate name for this changeably spreading creature, but "Proteus" had already been used generically for the little cave-dwelling amphibian of Adelsberg, and a new specific name was not wanted. See Dr. Leidy's concise and clear history of the nomenclature of this and other *Amœbæ* in his "Fresh-water Rhizopods of North America."

There are several varieties of *A. proteus*, one of which Prof. P. Martin Duncan has observed to habitually form only blunt or short lumpy pseudopods, but to move flowingly along quickly, with constant change of form, between nearly globular and somewhat cylindrical shapes. In time it becomes quiescent and round; and after parting with some of its contents, chiefly relics of food, it becomes encysted, and then bursts, giving birth to crowds of young individuals.

Another kind keeps its general outline more persistently than the other, but still creeps flowingly until a change comes, when it puts forth pseudopodial processes, and roams freely about, but afterwards attains an hibernating or quiescent stage. Having been shut up awhile in a closed membrane, like the other, it ultimately swarms with zoospores inside, and then they escape through the breaking of the capsule.

In its different stages *A. proteus* has been seen to vary in size and shape from globular 0·2 millimètre across, through ovoid 0·3 by 0·15 millim., dendroid 0·5 by 0·4, palmate 0·5 by 0·35, radiate 0·2 and 0·5 by 0·4, and cylindroid 1 millimètre long. The largest observed by Dr. Leidy occupied a space of 0·6 by 0·2 and 0·35 millim.

IX.—One particular kind of *Amœba*, which always has a tufted and knob-like extremity to its food-carrying, coarsely granular hinder moiety, has been named *A. villosa* by Dr. G. C. Wallich, who has especially studied, described, and illustrated the life-history of this and many other species of these *Protozoa*. *A. proteus* sometimes has a collection of little knobs or blunt papillæ (pimples) on its hinder end (see Fig. 3); but this other *Amœba* has always a villose or hairy ball-like end, with a narrow neck-like connection to the body. It begins as a small circular hairy patch, and is apparently sticky and prehensile, being often clogged with dirt.

This *Amœba* does not use pseudopods so freely as *A. proteus*. It grows to a much larger size ($\frac{1}{50}$-inch) than that species; but, as in that so in this, the end of the individual is a quiet rounding up and a sudden bursting, with the outcome of innumerable spherules or germinal spores.

X.—There is a closely related form, but larger, and even less inclined to exsert pseudopods, using its villose end in moving like the tail-sucker of the leech. On account of its peculiarities, Dr. Leidy refers it to Greeff's *Pelomyxa*.†

XI.—An Amœban animal with permanent bundles of long cylindrical tubular filaments trailing from its hinder portion has the appropriate name of *Ouramœba*.‡

XII.—*Deinamœba* § is a name given by Leidy to a curious villose Amœban animalcule, about 0·2 millim. in diameter, which has the peculiarities (1) of having the body and the pseudopods sometimes papillose, sometimes bristling with minute, stiff, pointed filaments; (2) of having at times an enveloping layer of delicate, transparent, jelly-sarcode, itself covered with similar needle-like filaments; (3) of extreme variability of form, chiefly round, ovoid, and sub-cylindrical. "Indeed,

* *Proteus*, the changeable sea-god. † Greek, *pelos*, mud; *myxa*, mucus. ‡ Greek, *oura*, a tail; *amœba*.
§ Greek, *deinos*, terrible; *amœba*.

no portions of the exterior of *Deinamœba* are constant, although they usually seem to be so. Head and tail appear to be mutually interchangeable; and such also is the case with the processes I have for convenience distinguished as pseudopods and papillæ."*

XIII.—F. E. Schulze's *Mastigamœba*† and the *Dactylosphærium*‡ described by Hertwig and Lesser, are said by Leidy to have some resemblance to *Deinamœba*. But the former, about 1 millim. long, is broad, and tapering at the ends, with many pseudopods and a general investment of minute spiculate bodies, different from those of *Deinamœba*, and a long flagellum projecting in front from an ovate corpuscle, enclosing a nuclear body. (See Fig. 4.)

The latter has no flagellum, is irregularly round, 0·06 millim. in diameter, with somewhat conical blunt pseudopods in all directions; and one variety has minute villi of protoplasm, also differing from those of *Deinamœba*.

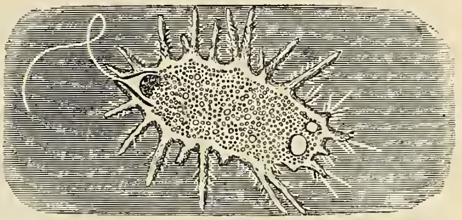


Fig. 4.—MASTIGAMŒBA ASPERSA, AS SEEN CREEPING OVER THE FIELD OF THE MICROSCOPE.
An intermediate form between the Rhizopoda and the Flagellate Infusoria. Highly magnified. (*Copied from Allman, after Schulze.*)

XIV.—*Podostoma*§ has relatively large pseudopods for locomotion, and others for feeding.

XV.—Among other Amœbans we may note *A. polypoda*, found by Max S. Schultze in the lagoon-water at Venice. This is near *A. radiosa* of fresh water. His *A. porrecta*, from the Adriatic, differs from a true *Amœba* in its delicate and branching pseudopods. Wallich, however, has pointed out that here, and sometimes with *A. villosa*, the usual short thick pseudopods are replaced by the finer filaments characteristic of the Filose Amœbans; and that we must not draw too sharp a line in classification when only one, and that not an essential, feature is used for the basis in grouping.

XVI.—The Amœban animalcules which we have already mentioned are members of the group known as the *Naked lobose* Rhizopods; and these are necessarily of the highest importance to the naturalist searching for explanations of the ways and means of all *Rhizopoda;* for, being transparent, or nearly so, they allow of a direct scrutiny into their internal organs (if their differentiated parts may be so termed), and such an insight to be got of their physiological functions as comparisons with other known organs and functions will enable us to make. There are other closely-allied Rhizopods with thick pseudopods, but they have delicate coats, tests, or shells, of various composition and structure, and yet for the most part not interfering with a direct acquaintance with the interior of the animal. They creep along with the aperture of the shell downwards, and the pseudopods, spreading out from it, attach themselves to the surface on which they crawl.

XVII.—Of these "Shelled Lobosa," the *Difflugia*‖ is one of the most common kinds, and comprises many so-called species, which, however, together even with some allied genera, are probably only varieties of one typical form. The shell is very variable in shape and substance; globular, or oval, with or without a neck, like a balloon, an urn, an amphora, a pitcher, a vase, a broad-mouthed flask or bottle, with endless modifications; opening downwards at what is usually the narrow end; the base sometimes pointed, instead of being round or flat, and the sides occasionally armed with spikes; the shell in many cases oblique, one-sided, or otherwise asymmetrical, and even partially curved on itself, like a chemical retort, when, as Dr. Wallich has explained, the animal has adhered to some object under the influence of a current of water pushing it over to one side. Its composition is tough in tissue, like chitine; but it has been originally soft enough (or has had an occasional overcoat thrown back over it soft enough) to be encrusted with embedded sand, Diatoms, spicules, &c., sometimes neatly fitted together, or even arranged with a parallelism when the component Diatoms are large and long.

In allied forms (*Quadrula*, &c.) the envelope has hardened in segments on some geometrical plan, so that it is formed of little tablets, six-sided or square, edge to edge. Whether the tough test-matter is secreted by the ectosarc, or the latter becomes superficially consolidated, is not known.

* Leidy, *Op. cit.*, p. 87.

† Greek, *mastix*, *mastigos*, a whip; *amœba*.

‡ Greek, *dactylos*, a finger, or a date; *sphaira*, a sphere or ball.

§ Greek, *pous*, a foot; *stoma*, a mouth.

‖ Latin, *diffluo*, I flow in different directions.

The sarcode almost fills the interior, and is attached inside by threads of ectosarc to the hollow sides and the base; and it stretches to the mouth, whence it sends out about half a dozen simple or branching pseudopods, and occasionally protrudes a large lump of its sarcode, usually soon retracted. The food is, of course, taken in by that aperture, and the effete remnants are ejected thence at the base of the pseudopods. Nucleus and contractile vesicle exist as in the naked *Lobosa.*

XVIII.—*Hyalosphenia** is much like *Difflugia*, but has a transparent, structureless, bag-like test, of a flattened-ovoid shape; and gives out only a few finger-like pseudopods.

XIX.—*Quadrula*† is a very delicate and neat *Difflugia*, with pear-shaped test, composed of thin square plates symmetrically arranged.

XX.—*Nebela* is another Difflugian genus well known in its many "species," having a pear-shaped, transparent, cancellated, membranous test, made up of circular, oval, narrow-rectangular, and narrow-angular plates, occasionally more or less invested with extraneous particles, and sometimes crested, hirsute, or spiked.

XXI.—*Heleopora*‡ is another closely related form, separated and named by Leidy because of certain peculiarities in its plating, in its taking on sand at its rounded base, and its numerous pseudopods.

XXII.—*Arcella*,§ one of the commonest of the shell-bearing Rhizopods found in fresh water, may be said to be like a flattish bell, a buckler, or a bun with a hole in its flat base, or a cap (Scotch "bonnet"), each liable to various symmetrical squeezings of the sides and margin; sometimes turned up with sharp angles and long points. The shell is tough, not sandy, usually brown, and cancellated with a delicately minute hexagonal pitting. The edge of the aperture, which is large, is frequently turned inwards and upwards to some extent. The pseudopods are few and simple.

There is also a terrestrial *Arcella* (*A. arenaria*), described by Dr. Greeff.

XXIII.—*Centropyxis*‖ is a common form, allied to *Arcella*, but not so symmetrical. Sub-globular and depressed, sometimes spiky. Aperture not in the middle. Test sandy, as in *Difflugia.* Pseudopods simple.

XXIV.—*Cochliopodium*¶ is a curious Amœban, putting on very enigmatical appearances according to its changes. It is bell-shaped, with a flexible test, sometimes expanding widely at the aperture, which contracts or enlarges as the margin is bent in or out. The sarcode fills up and adheres throughout to the inside of the envelope. Pseudopods delicate, sometimes forking.

The above and other shelled Amœbans live in fresh water.

XXV.—Another group of fresh-water Rhizopods are those having thread-like branching pseudopods (hence termed *Rhizopoda filosa*, or *R. filigera***), but otherwise the same general constitution and form as the Shelled Lobose species.

Their sarcode is generally like the endosarc of the *Lobosa;* the delicate "pseudopods appear as filaments of the finely granular protoplasmic basis of the sarcode;" and their branches seem to be only entangled in capturing prey, and not to blend or pass one into another. The tests are egg-shaped, or like bags or flasks, &c., similar to those of the *Lobosa*, but generally more delicate, and not so various in form, but always opening downwards, and sometimes excentric.

Pamphagus,†† *Euglypha*,‡‡ and *Trinema*§§ are some of the most common and best-known of the *Filosa.*

XXVI.—Both the naked and the shelled *Amœbina* (Leidy's *Protoplasta lobosa* and *P. filosa*) have their sarcodic contents encysted in a quiescent stage, the body having been purged of all effete matter; and the little globular mass ultimately breaks up into spherules, which are germs or spores in all probability. Dr. Leidy notes that "From the researches of Mr. Carter‖‖ it would appear that in *Amœba* and *Euglypha*, representatives of the Lobose and the Filose Protoplasts, the endosarc becomes resolved into nucleated cells, which are of the nature of ova; while the nucleus is resolved into granuliferous, non-nucleated cells, finally breaking up into their constituent granules, which are of the nature of spermatozoids."¶¶

* Greek, *hyalos*, crystal; *sphen*, a wedge.
† Latin, diminutive of *quadrus*, square.
‡ Greek, *helos(-eos)* a bog; *pera*, a bag.
§ Latin, *arca*, a box.
‖ Greek, *centron*, a prickle; *pyxis*, a box.
¶ Greek, *cochlos*, a shell-fish with spiral shell; *pous*, a foot.
** Latin, *filum*, a thread; *gero*, I bear.
†† Greek, *pamphagos*, all-devouring.
‡‡ Greek, *eu*, well; *glyphe*, sculpture.
§§ Greek, *tri*, three; *nema*, thread.
‖‖ "Annals and Magazine of Nat. Hist.," 1856, vol. xviii., p. 226.
¶¶ Greek, *sperma*, seed; *zoön*, an animal; *eidos*, appearance.

XXVII.—Another kind of Rhizopod, also inhabiting fresh water like the foregoing, are the Sun-animalcules, or *Heliozoa*.* These, however, float free in the water, and have round bodies, with delicate pseudopods radiating from all parts of the surface, producing a very gentle gliding movement, and serving to capture prey. The sarcode in these animalcules has usually a yellowish tint, and contains many clear globules or water-cavities, giving it a foamy appearance. Sometimes it is green with either granular or diffused chlorophyll, derived from minute *Algæ* taken in as food. There are often red spots, also due to *Algæ*. Besides one or more nuclei, there is a conspicuous contractile or pulsating vesicle (sometimes more than one); and this in its action rises like a bubble above the level of the surface, in some species, and bursts so violently, as to shake the whole animal and to make the discharge of its contents evident in the surrounding water.

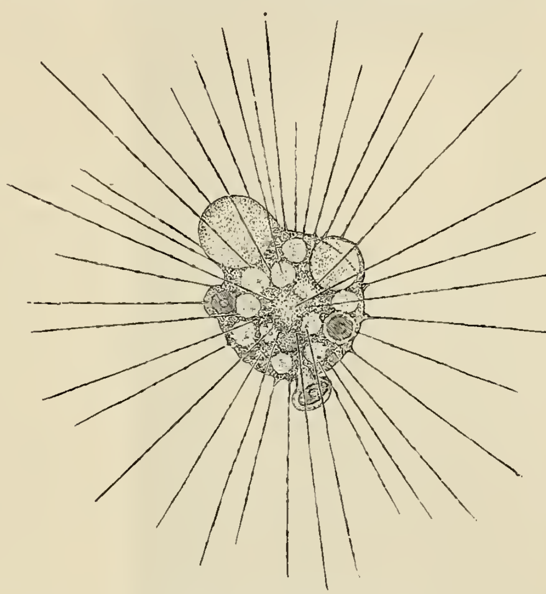


Fig. 5.—ACTINOPHRYS SOL.

The light spots are vesicles and water-cavities. The projecting globule is a contractile vesicle about to burst. The dark spots are green zoöspores of *Algæ*, taken in as food. The pseudopods are here made much too thick. Magnified 500 diameters. (*After Leidy.*)

Their body often presents the appearance of a central granular mass, enclosed in a capsule, but this is much more evident in some of the allied marine *Radiolaria*.† The pseudopodia are thin threads of granular protoplasm, tapering to extremely fine filaments, rarely forked or branching at the ends. Though straight, they are not rigid, but flexible and contractile, drawing the food-atoms they touch towards the body, where the particles are enveloped by the sarcode and taken inside. In some cases the pseudopods are said to be strengthened by an internal axis of tougher material. Sometimes the animalcule seems to stand, as it were, on the ends of the pseudopods touching the object beneath.

Most of the *Heliozoa* are soft and naked; but others have an extremely rudimentary skeleton of silicious ‡ spicules in the outer layer of sarcode; and some have a more developed and delicate shell, of the same mineral substance, like lattice-work, forming an elegant trellised sphere.

This group corresponds to some extent with the marine *Radiolaria*, and is termed "Fresh-water Radiolarians" by some; but they have a greater simplicity of constitution than most of the former.

XXVIII.—*Actinophrys*§ *sol* (Fig. 5), "the common Sun-animalcule, is one of the most familiar and striking forms of microscopic life of still fresh water. . . . It may be found in almost every standing water-pool, pond, or lake, swimming among aquatic plants; its favourite haunts being duck-meat, hornwort, bladderwort, or the various filamentous Algæ. It commonly appears as a globular hyaline, foamy, or vesicular body, bristling with delicate rays, and suspended almost stationary in the water." (Leidy.) It is about $\frac{1}{12}$th millimètre in size, and feeds on Rotifers, Infusoria, unicellular Algæ, and Zoospores. Active animalcules touching its rays often seem to be paralysed. Small prey glides down the pseudopods to their roots, where sarcode protrudes and takes it in. Dr. Wallich, in one of his memoirs, has figured an *Actinophrys* becoming itself a prey to a large *Amœba*, which tore it piecemeal by means of its pseudopods, and engulfed a moiety of it lump after lump. In his description of this circumstance, that careful naturalist remarks that, however successful the stolid energy of the *Actinophrys* usually may be, yet when an *Amœba* comes to the front the former avoids it; but the latter with unusual activity endeavours to seize and to envelope, or at least to tear out portions of the *Actinophrys*.

* Greek, *helios*, the sun; *zoön*, an animal. † Latin, *radiolus* (diminutive of *radius*), a little staff or rod.

‡ Latin, *silex*, quartz or flint; used for the kind of mineral comprising both these and other varieties of *silica*.

§ Greek, *actis*, a ray; *ophrys*, the eyebrow.

XXIX.—*Heterophrys** has an external villose or velvety layer of sarcode.

XXX.—*Raphidiophrys*† is an Actinophryn with a thick external layer of delicate sarcode, which is full of minute silicious (?) spicules, and extends for some way along the pseudopods.

XXXI.—*Vampyrella*,‡ an animalcule not yet well understood; by some regarded as an Actinophrys, capable of Amœban variations of form, and making finger-like, lobate, and wave-like expansions of its sarcode. The presence of a nucleus is doubtful; and one marine form, having no nucleus, is placed by Haeckel among his *Monera*. The fresh-water *Vampyrella* feeds on the cells of the little *Alga* called *Spirogyra*. Creeping on a filament, it perforates cell after cell, transferring the contents to its own interior. The marine *Vampyrella*, in like manner, feeds on the *Gomphonema*.

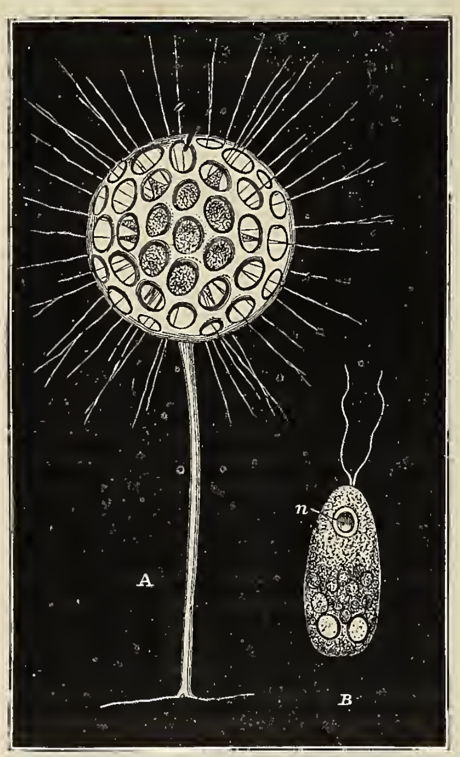


Fig. 6.—CLATHRULINA ELEGANS.

A, Completely developed: magnified more than 300 diameters; B, a zoöspore, or "Swarm-spore," with two flagella, a nucleus (*n*), and several contractile vesicles (white spots). Very highly magnified. (*Copied from Allman, after* (A) *Greeff and* (B) *Hertwig and Lesser.*)

XXXII.—*Diplophrys* § is very minute, associated in groups while young, but isolated when full grown; it then has a delicate envelope which permits of the extrusion of only two tufts of attenuated pseudopods.

XXXIII.—*Actinosphærium*|| is larger than the Sun-animalcule, sometimes 0·4 millimètre in diameter; it looks much like it, and its habits are very similar, but it is rarer, and the outer or clear vesicular portion is very distinct from the interior clouded, though still vesicular mass. The pseudopods are more distinctly strengthened by a stiffer internal axis than in *Actinophrys*; and yet the pseudopods can be retracted; and sometimes they wholly disappear.

XXXIV.—*Acanthocystis* ¶ is like an *Actinophrys*; but it has in some cases an external coat of delicate protoplasm, full of exceedingly fine spicules (as in *Raphidiophrys*); and also, besides thin pseudopods all over the surface, it has numerous long silicious spicules or rays, often forked at the end, standing out from every part of the body.

XXXV.—*Hyalolampe* ** has a body invested with minute, clear, silicious globules.

XXXVI.—*Clathrulina*†† has an Actinophryan body invested with an elegant, globular, silicious trellis, through which the pseudopodal rays project; and this spherical latticed or fenestrated ‡‡ capsule is attached by a long, thin, silicious stem or "pedicle" to water-plants (Fig. 6). Young individuals without the lattice skeleton rise from, and are attached to, the old ones. Adult forms, however, have been seen which have divided, within the skeleton, into two or four parts, each of which became encysted, and ultimately gave birth to a minute, nucleated, swimming atom; and this by-and-by became furnished with a trellis-coat and a fixed pedicle.

XXXVII.—*Zooteira* §§ is also an Actinophryn with contractile pointed filaments, and elevated on a pedicle; but this is contractile, and not silicious; and there is no skeleton.

XXXVIII.—Besides the *Heliozoa*, the *Radiolaria* comprise other kinds of Rhizopods. These are marine, floating at or near the surface of the sea. Most have silicious frameworks; and their bodies are often of bright colours (yellow, red, violet, and blue, especially), either in spots or diffused generally. One set (Plagiacanths||||) have their sarcodic body divisible into a clear, toughish

* Greek, *heteros*, diverse; *ophrys*, an eyebrow. † Greek, *raphis* (—*idos*), a needle; *ophrys*, an eyebrow.
‡ From "Vampyre." § Greek, *diploos*, double; *ophrys*, an eyebrow. || Greek, *actis*, a ray; *sphaira*, a sphere.
¶ Greek, *acantha*, a thorn; *cystis*, a pouch. ** Greek, *hyalos*, crystal; *lampe*, foam.
†† Latin, *clathri*, a lattice. ‡‡ Latin, *fenestra*, a window. §§ Greek, *zoë*, life; *teiro*, I rub.
|||| Greek, *plagios*, oblique or transverse; *acantha*, a thorn or spine.

ectosarc and a granular and highly-coloured endosarc (sometimes bright red), enclosing a large central body with a membranous envelope.

Vacuoles, and many minute yellow bodies—the latter defined by Wallich as "sarcoblasts,"—such as occur in very many other Rhizopods, and serve as their ovules, are also present; and there is the usual kind of protoplasmic circulation. In many forms there is a silicious skeleton, either of interlacing spicules, or of connected rods and meshes, or a perforated spherule, constituting, under various modifications, exquisitely beautiful crystal basket-work, lattices, or trellises, surpassing even the perforated, ivory-nested capsules of the neatest and most elaborate Chinese carving. In this character of silicious basket-work, they resemble those Radiolarians which possess no nucleus or contractile vesicle, and are specially known as *Polycistina.* *

XXXIX.—Of the Plagiacanths, as defined by Dr. Wallich, the *Acanthometra* † (Fig. 7) heads a numerous and important group. *Xiphacantha* ‡ (Fig. 8) is one of them, and has a silicious skeleton of twenty long, sharp, regular, radiating rods or prickles, the bases of which fit neatly together in the central capsular body. Just within the surface of the body, and parallel to it, each gives off symmetrical cruciform branches, which constitute altogether an open spheroidal lattice-work.

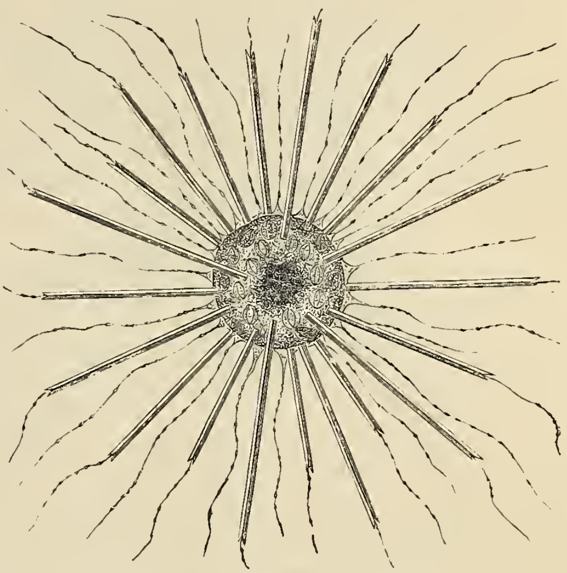


Fig. 7.—ACANTHOMETRA ECHINOIDES.
Highly magnified. (*After Claparède and Lachman.*)

XL.—*Stylodictya* § (Fig. 9) belongs to a series of more or less discoidal forms, composed of two parallel, perforated, or reticulate plates, coalescing round the margin (from which spines project at regular distances), and separated elsewhere by an intermediate series of concentric or spiral rings.

XLI.—*Thalassicolla* || is one of the marine nucleated Radiolarians without a skeleton. *Acanthodesma,* ¶ an allied form, has a loose network of spicules for a skeleton; and, in other forms belonging to this group, there are various modifications of rods and rays.

XLII.—In the *Collosphæra* ** and in *Sphærozoum,* †† numerous minute nucleate individuals are associated in a relatively large gelatinous mass. In the latter species, each zoöid has silicious spicules, but in the former each has a simple perforated or fenestrated spherical skeleton.

XLIII.—Artificially arranged among the *Radiolaria,* on account of the structure of their skeleton, are the *Polycistina;* but Dr. Wallich recognises in them neither central nucleus nor any contractile vesicle, sarcode not differentiated into endosarc and ectosarc, some vacuoles, the pseudopods frequently anastomosing, and showing the usual kind of circulation. Their silicious skeleton, generally globular, is variously trellised, and sometimes composed of two, or even three, concentric basket-balls, supported and separated by few or many long radiating spicules, passing from the centre to beyond the surface. These rays commence from a central base ("omphalostyle" ‡‡ of Wallich), either symmetrical in a spherical chamber, in his "*Cyclolina*" (circular), with *Haliomma,* §§ *Amphidiscus,* |||| and *Astromma* ¶¶ for types, or asymmetrically, as in his "*Monodina*" (single), with *Podocyrtis* for their type.

* Greek, *polys,* many; *ciste,* a box.

† Greek, *acantha,* a thorn; *metron,* a measure.

‡ Greek, *xiphos,* a sword; *acantha,* a thorn.

§ Greek, *stylos,* a column; *diktyon,* a net.

|| Greek, *thalassa,* the sea; *colla,* glue, jelly.

¶ Greek, *acantha,* a thorn; *desmos,* a chain.

** Greek, *colla,* jelly; *sphaira,* a sphere.

†† Greek, *sphaira; zoön,* an animal.

‡‡ Greek, *omphalos,* a navel; *stylos,* a column.

§§ Greek, *hals,* the sea; *omma,* an eye.

|||| Greek, *amphi,* round-about; *discos,* a quoit.

¶¶ Greek, *astron,* a star; *omma,* an eye.

*Podocyrtis** (Fig. 10) has a fenestrated, casque-like skeleton, globular where largest, then tapering, and then spiked, at one end; and open, with three marginal prickles, at the other.

Eucyrtidium† (Fig. 11) is a Polycistine, with a nearly conical reticulate skeleton, somewhat like a high-peaked Indian helmet of chain-mail.

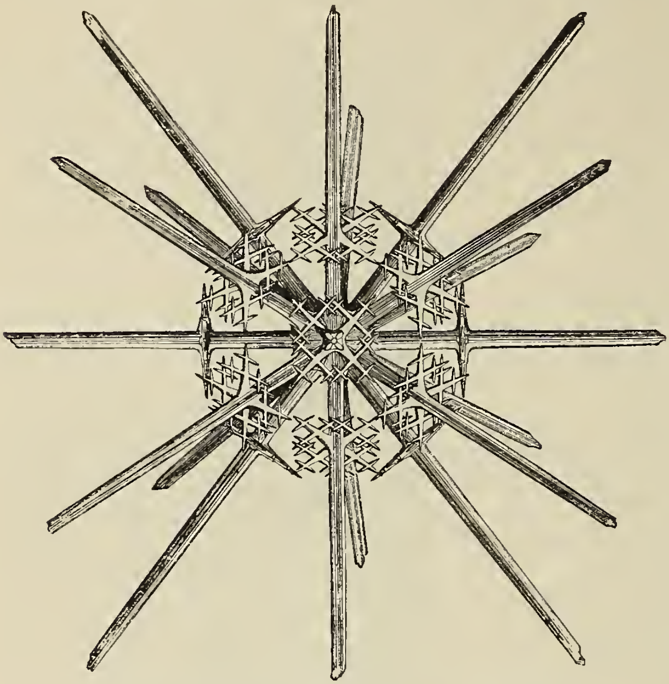
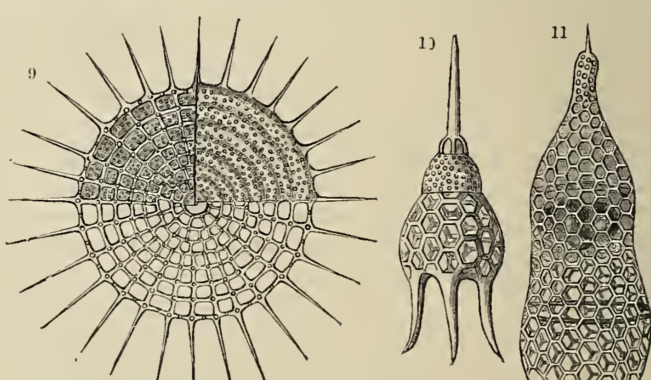


Fig. 8.—XIPHACANTHA MURRAYANA. (*After W. Thomson.*)
The skeleton of a Radiolarian of the *Acanthometra* type. Magnified 100 times.

Eucecryphalus‡ (Fig. 12) has a beautiful umbrella-shaped lattice as a protection to its soft vesicular body.

The *Polycistina* are enveloped in a delicate filmy investment of sarcode, when alive; and their sarcoblasts or ovules are abundant. However complex the skeleton may seem to be in any of these Radiolarian forms, we must recollect that it is a feature of less essential value in biological classification than the internal organs. Therefore the *Polycistina* are low in the scale (just below the *nucleated* Radiolarians); and, unless a "nucleus" should be decidedly found in the *Foraminifera*,§ these latter come last of all, among the interesting and great family of RHIZOPODA.

XLIV.—In the last-mentioned group we find the pseudopodia branching out and blending one with another, and thus forming a mesh-work or reticulation. Hence the *Foraminifera* have been placed among the *Reticularia*,‖ whenever the pseudopods have been taken for chief guidance in grouping the forms. Some of the *Polycistina* have a tendency to this habit.



Figs. 9, 10, 11.—RADIOLARIAN SKELETONS, OR LATTICED SILICIOUS SHELLS. Highly magnified. (*After Haeckel.*)
Fig. 9, *Stylodictya multispina* (*Haeckel*), living off Messina: Fig. 10, *Podocyrtis Schomburgii* (*Ehrenberg*), fossil from Barbadoes; Fig. 11, *Eucrytidium lagena* (*Haeckel*), living off Messina.

One kind of Reticulose Rhizopods (*Lieberkühnia*) has neither nucleus nor contractile vesicle, and is therefore very low in the scale of being; others (*Biomyxa* and *Gromia*) have both these endoplasts, or protoplasmic organs, and therefore rank as high as the Amœbans. As to their habits, some genera have representatives in both fresh and salt water (*Gromia* and *Lieberkühnia*), some only in fresh water (*Biomyxa*), some only in salt and brackish water (*Foraminifera*).

The *Reticularia*, or Reticulose Rhizopods, protrude many long thread-like pseudopods, which

* Greek, *pous*, a foot; *cyrte*, a fish-basket. † Greek, *eu*, good; *cyrte*. ‡ Greek, *eu*, good; *cecryphalos*, a hair-net.

§ Latin, *foramen* (*foraminis*), a hole; *fero*, I bear. This name was given to them originally, not on account of the superficial perforations, but because their dividing walls have one or more simple holes; and these were thought to constitute a distinction from the tubed apertures in the divisions of the cephalopodous shells with which they were then confounded.

‖ Latin, *reticulum*, a little net or a network.

frequently blend together here and there, away from the body, or "anastomose" among themselves so as to form irregular meshes of sarcode. Some of these animalcules possess the important "nucleus" (*Sheepheardella*, Siddall), and one or more "contractile vesicles" (*Biomyxa*, Leidy; and *Gromia*, according to Wallich). Among the Foraminifera, some are said to have yielded evidence of the presence of a "nucleus." But it is possible that these apparently nuclear bodies are "sarcoblasts," either isolated or in groups, especially when the granular forms have come to light by the intervention of re-agents.

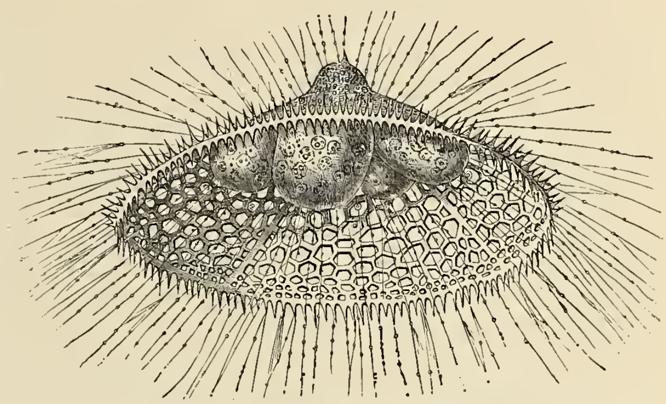


Fig. 12.—EUCECRYPHALUS SCHULTZEI.

A living Radiolarian of the Cyrtidan family; off Messina. Highly magnified. (*After Haeckel.*) This is tipped up a little, so as to show the body with its sarcoblasts inside.

In effect, fresh specimens show nearly clear and quite pale "nuclei," or none at all; and those subjected to re-agents show granular bodies, like "nuclei," pale or darkish, and sometimes with a central spot, either dark or pale. In the first case, the presence of definite globular bodies, besides *nuclei*, in Rhizopods, must be thought of; and, in the second case, the effect of chemical re-agents on the (1) sarcodic granules, and (2) on the endoplasts (sarcoblasts) in Rhizopods, must be allowed for before the above-mentioned corpuscles in certain *Miliolæ* and *Planorbulinæ* (?) can be regarded as true *nuclei*.

XLV.—*Lieberkühnia** is a simple, granular, non-nucleated, thin-skinned Rhizopod, with vacuoles. It is egg-shaped, and sends off from one part of its body a stem-like process, at first within a filmy coating of the general sarcode, but soon branching off again and again into finer and finer filaments. These coalesce freely, and form islets here and there among the shifting and changing reticulations. The granules of the protoplasm have the usual circulatory movement, somewhat like that visible in *Valisneria*, *Nitella*, and other plants, but of a different physiological character, not being so regular, and evidently more dependent on the actual movements of the animal. This rare animalcule was first described and figured by Claparède and Lachman in their "Les Infusoires et les Rhizopodes." Mr. Siddall has lately found it in sea-water.

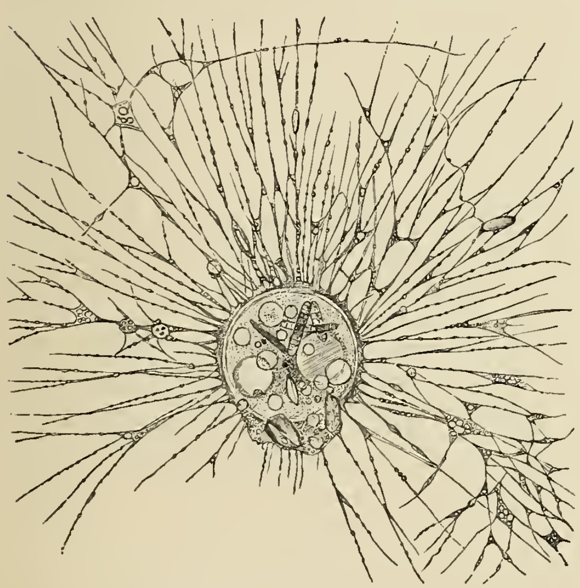


Fig. 13.—GROMIA TERRICOLA.

Animalcule with a filmy coat of sarcode and extended, interlacing, and reticulate pseudopods. The transparent envelope shows a large nucleus, vacuoles, oil-globules, and food within. Sand and dirt adhere at the hinder end (below). Magnified 200 diameters. (*After Leidy.*)

XLVI.—*Biomyxa*,† discovered by Dr. Leidy, has been described by him as a fresh-water Rhizopod, soft, glairy, colourless, unconfined by any external envelope or test, and incessantly changing in shape. It has one "nucleus," or more, and several "contractile vesicles," in its spherical state, and sends off numerous attenuated and anastomosing‡ pseudopods. Granular "circulation" is seen in

* *Lieberkühn*, a famous microscopist.

† Greek, *bios*, life; *myxa*, mucus.

‡ Greek, *ana*, through, among; *stomoo*, I furnish with a mouth, I open. Applied originally to the junction of veins and tubules, whereby they open one into another.

the sarcode of the body and the filaments. Blended portions of the latter, seemingly detached by accident, continue to exist as non-nucleated Rhizopodous organisms.

XLVII.—*Gromia*, discovered by Dujardin in both salt and fresh water, is a round or egg-shaped little mass of granular sarcode, with relatively large central nucleus, vacuoles, contractile vesicle (seen by Wallich), and a tough membranous investment. The last is thin, transparent, and usually open at one end only, whence the sarcode is extruded. This stretches forth in thin branching pseudopods, and also extends itself as a film back over the whole of the test, giving off long delicate pseudopods from its general surface. These are continually changing in direction and extent, uniting and disuniting among themselves, or moving as lashes, spirals, and otherwise. At their unions they form islets of sarcode, which become the centres of secondary nets.

A very interesting kind of *Gromia* (Fig. 13), found by Dr. Leidy among the damp moss of his house-yard in Philadelphia, is named by him *G. terricola*. It is about twelve millem. in diameter; and with its pseudopodial net fully spread, this *Gromia* looks somewhat like a spider in its web. Its food consists of "minute Diatoms, fragments of Lyngbya, and globular green Algæ." It takes in some sand also.

XLVIII.—Many of the Reticularian Rhizopods have a calcareous shell, not a merely spicular or fibrous, basket-like skeleton, like a Radiolarian silicious framework, but composed of definite chambers or compartments, sometimes one, often more, in regular sequence on a straight line, or bent, coiled, alternating, concentric, or even irregularly heaped, in almost endless modifications. These lime-made shells are thus either simple or compound, containing—(1) only one round, oval, or elongate morsel of sarcode; or (2) more than one, sometimes very many such little bodies in one shell, which is chambered or divided according to the number of segments of sarcode constituting the whole animalcule.

On account of this latter condition, these calcareous-shelled *Reticularia* have been termed *Polythalamia.** The first-mentioned, or single-chambered ("monothalamous") condition, whether regarded as a special form, or as an exception to the general rule, being due either to immature, imperfect, or varietal growth, at all events vitiates the application of "Polythalamia" to the whole of the group.

The walls separating the chambers of the compound shells are pierced with either one or many holes, for the passage of a thread ("stolon†") or threads of sarcode, by which the segments are connected together, and by which, indeed, each new segment stretches, buds, or grows out from the older portion of sarcode. These simple holes in each separating wall ("septum‡") of the chambers in those of the compound shells which look like little Ammonites and Nautiluses were at first thought to constitute a distinction between those high-class Molluscs which have tubes ("siphons" or "siphuncles") from chamber to chamber, and these minute shells, which were at that time mistakingly referred to that class; and thus they were called *Cephalopoda foraminifera*, to distinguish them from the *Cephalopoda siphonifera*. Although this mistake was soon corrected, the word Foraminifera has been kept for these Reticularians under notice.

Some wrongly think that the name is due to the fact that in many instances the whole of the outside shell is perforated with either small holes or minute tubules. In this latter sense, however, the name would not be applicable to the whole of the group; for in a large and important division the general shell is not pierced with any holes, but has solid walls except at the single aperture whence the sarcode pushes out an external filmy coat and pseudopods, or buds out on a new stolon (Fig. 14).

Hence *Foraminifera* are divisible into two main groups:—1. The imperforate (*imperforata*), or porcellanous (*porcellana*); 2. The perforate (*perforata*), or glassy or vitreous (*vitrea*, also *hyalina*), on account of their relative translucency. There is also an intermediate group, called the arenaceous, or sandy (*arenacea*), some of which seem to belong to the one, and some to the other of the foregoing divisions.

Still there are even in these groups, however distinct they may appear to be at first sight, links

* Greek, *polys*, many; *thalamos*, bed or chamber.

† Latin, *stolo* is used by botanists for a kind of root; from Greek, *stolos*, a setting-out or a source.

‡ Latin, *septum*, a hedge or wall.

of alliance (beside their pseudopodial and physiological characters), as well as exceptions in their structural characters; for (1) some individuals of the porcellanous one-mouthed kind have connecting passages between their inner chambers; (2) some of the perforate forms begin with the usual hyaline shell-structure, but become coarse, imperforate, and sandy with advancing age. (3) Moreover, some of the smooth *porcellana* become sandy as they grow. (4) Some, also, of the same kind secrete little or no shell-matter, and have sometimes merely a covering of membranous consistence, like that of some of the shelled Amœbans, many of which latter group we may remark, though they are not calcareous, have the habit of taking up sand to stiffen their tests. (5) Some of the arenaceous kinds send out pseudopods from between the sand-grains embedded, but not cemented, on their surface, and do not appear to have the usual large aperture for the stolon; and there is said to be even a simpler kind, merely a little morsel of sarcode containing sand, not as a coating, but mixed up vaguely with it,* more abundantly, it seems, than the grains of sand found in some of the more gluttonous and coarse-feeding of the *Amœba*, and serving perhaps to give a kind of general stability to the little Moneral organism. The largest known of the *Arenacea* are *Parkeria* (after *W. K. Parker*), and *Loftusia* (after *W. K. Loftus*).

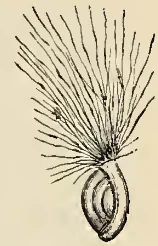


Fig. 14.—MILIOLA (QUINQUELOCULINA).

One of the "Porcellanous" Foraminifera; living. (*After Schultze.*)

Those *Foraminifera* which have a white, opaque or compact, non-porous, porcellanous shell, without perforations for the passage of pseudopods from every part of the enclosed body, comprise six well-known typical forms. Around these an almost endless series of more or less allied forms, having the same essential characters, but varying in modes of growth, and often almost imitating one another, especially in their young stages, may be grouped by zoologists. There is, first, the *Cornuspira* (horn-coil, Fig. 16_4), a simple thread of sarcode coiling flatwise, and coated with the usual opaque shell open at the end. Becoming constricted at intervals, and losing its circularity, it seems, if we put all the varying individuals in a series, to pass into a *Miliola* (millet-seed), which is folded up and down, and is pinched in at the turns—whether these come exactly opposite to each other on the two sides of the shell, as in *Biloculina* (two-chambers) and *Spiroloculina* (spiral chambers, Fig. 16_2); or do not equally match on opposite sides, but leave three or five folds visible on the unequal faces, as in *Triloculina* and *Quinqueloculina* (three and five chambers, Figs. 14, 16_3). Some individuals when young, and even in the adult state, make but an imperfect second chamber in the turn of the shell; and, beginning like the retort-shaped *Difflugiæ*, seem to fail in advanced growth, as the *Adelosina* (not manifest, or uncertain). The *Miliolidæ* may be said to be cosmopolites, in all seas; and they are frequent in a fossil state, especially at Paris. Again, some begin with the circular, or with the alternate or agathistegian (ball-of-thread-like) folds, but go off with a straight growth, chamber after chamber—sometimes narrow, as *Articulina* (joint-like), or broader as in *Vertebralina* (vertebra-like), common in the Red Sea. In all these the terminal aperture, whatever its relative size may be, gives out the sarcode to make pseudopods, but not to go back over the whole shell as a coating film.

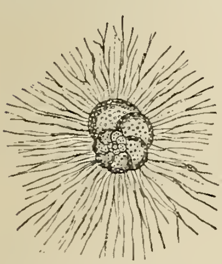


Fig. 15.—DISCORBINA. (*After Schultze.*)

One of the "Vitreous" Foraminifera: living.

Another kind of shell among the porcellanous group has often a delicate pearly whiteness; and begins with one globule of sarcode, which gives off by one stolon a half-moon-shaped segment, which, in its turn, gives off two or more stolons, and a larger, curved, narrow segment; and this produces a transversely-longer crescentic addition with additional parallel and advancing stolons, until chamber after chamber lengthens and widens the shell in its growth, often curving elegantly (on a plane). It is pierced at its terminal edge either with separate holes or a branching rift (as if the holes had run one into another); and thus we have the *Peneroplis* (a fancy name), with perforate edge, or *Dendritina* (Fig. 30), with "tree-like" mouth. Often *Peneroplis* grows quite narrow and straight after a feeble youth of spiral growth, and then it is like a crozier. Common in the Red Sea and Mediterranean.

Orbiculina (circle-like) is formed on somewhat the same plan, but it is not so pearly, and from

* Carpenter, "Foraminifera," Encycl. Brit. ix., p. 375.

the first it sets on its new segments as nearly complete rings, close and neat, and with the sarcode even branching upwards into overlying rings, so as to thicken the early portion of the shell. But whether the flat compound shell is ear-shaped, and shows a delicate concentric spire on its faces, or is discoidal, with rings almost truly concentric, its sarcode only comes out at the marginal pores of the last "annuli" (rings) of the shell, which, like the earlier narrow curved chambers, are usually (not always) subdivided in a uniform manner, corresponding to the external openings. These are abundant in the West Indies and elsewhere. *Alveolina* is, as it were, an *Orbiculina* rolled up on a long transverse axis. Fossil and recent.

Orbitolites, truly concentric from its first growth, has larger chambers (segments of sarcode) than *Orbiculina*, though some of the two kinds are distinguishable with difficulty; it is also more free

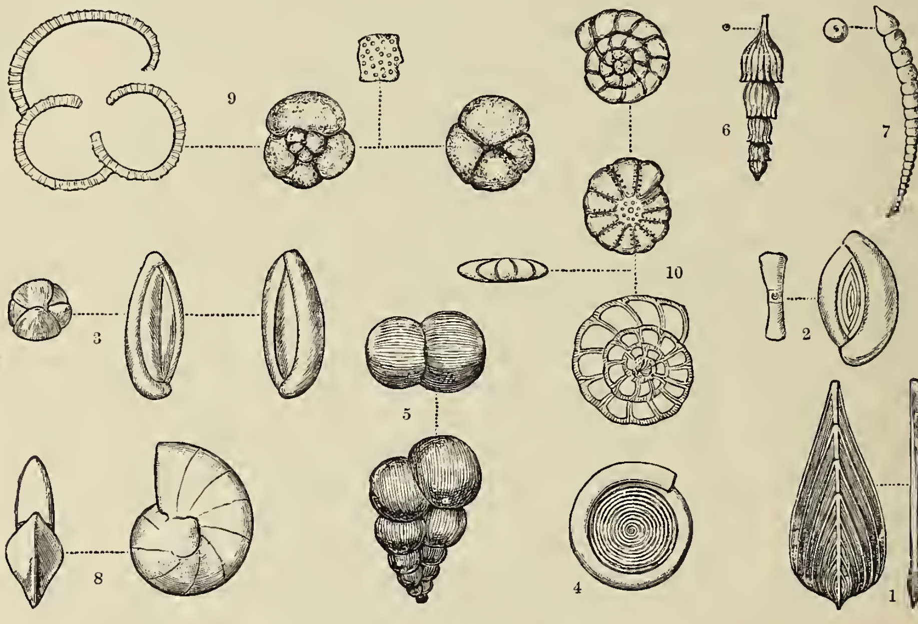


Fig. 16.—VARIOUS FORMS OF FORAMINIFERA.

1, Frondicularia Goldfussi, *Reuss*. Cretaceous. Bohemia. 2, Spiroloculina badensis, *d'Orbigny*. Miocene. Baden, Vienna. 3, Quinqueloculina saxorum, *Lamarck*. Eocene. Paris. 4, Cornuspira polygyra *Reuss*. Oligocene. Hungary. 5, Textularia globifera, *Reuss* (striata, *Ehrenberg*). Upper Cretaceous Traunstein. 6, Nodosaria spinicosta *d'Orbigny*. Miocene. Vienna. 7, Dentalina elegans, *d'Orbigny*. Miocene. Vienna. 8, Cristellaria rotulata, *Lamarck*. Cretaceous. Bohemia 9, Globigerina conglomerata, *Schwager*. Pliocene, Kar-Nikobar. 10, Rotalia Beccarii, *Linné*. Pliocene. Sienna.—(*Copied from Zittel, after Reuss and others.*)

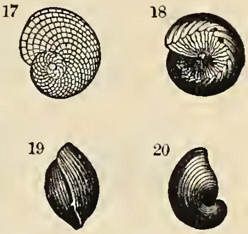
to grow thick in its outer rings. Each annulus is formed by the coalescence of the peripheral crop of buds, with a new stolon going off from between each pair of these new segments. This is famous as being one of the common fossil Foraminifera of the white friable limestone near Paris and elsewhere in N.W. France. It lives in the Australian seas, and thrives at Fiji and elsewhere.

An immense variety of forms can be grouped, according to more or less striking alliances, round the *Lituola* (little crozier), which is essentially an arenaceous *Foraminifer*, but has some allies, which, without losing touch of *Lituola* in some resemblance or other, are as porcellanous as *Miliola*, and others which, except for their sandiness, would belong to the hyaline or vitreous group.

Trochammina (wheel sand), fossil and recent, is usually a simple, flat-coiled shell, looking like smooth sandy plaster. But it may be otherwise twisted, and constricted at intervals. Thus one kind is called *T. gordialis* (Gordian knot); and another imitates a *Rotalia*. *Endothyra* (inside door), abounding in some Carboniferous strata in various parts of the world, is arenaceous, and of many forms. So also *Valvulina* (valve) and *Textularia* (plaited, Figs. 16_5, 25, 26), are sandy, but only with advancing growth. They have an *alternate* arrangement of chambers, but on different plans. Both also often grow on with a straight or linear set of chambers, as *Bigenerina* (double-kind, Figs. 27, 28,—a variety of *Textularia*). *Bulimina* (bulimus-like, Fig. 32), with an alternate growth,

but differing from the last both as to its aperture and its segmental plan, also becomes sandy in old age. The last three kinds are known both recent and fossil.

The truly hyaline *Foraminifera*, with very small perforations of shell, have the one-chambered *Lagena* (flask) for their simplest type. This is often most exquisitely delicate and elegant. In *Glandulina* (acorn-like, Figs. 21, 22) and *Nodosaria* (knotty, Figs. 16_6, 23, 24) we see a series of chambers planned on the growth of successive *Lagenæ*, the base of the new one partly enveloping the front of the last segment. The ornaments are various, but chiefly thin ribs and delicate points. If not circular in section, but flat, the same kind of growth produces *Lingulina* (tongue) and *Frondicularia* (leaf, Fig. 16_1). If round in section, but bent, it is *Dentalina* (tooth, Fig. 16_7). Still further curved, whether thick or thin, convex or flat, smooth or ornamented, this kind of Foraminifer becomes a *Vaginulina* (sheath), a *Marginulina* (margin), and in the extreme a *Cristellaria* (crest, Fig. 16_8). If the segments grow alternate, we have either *Polymorphina* (many-shape) or *Uvigerina* (grape-bearer, Fig. 33). The last is not so common as the others of the *Lagenidæ*, which abound both recent and fossil. Another set of hyaline Foraminifers has coarser pseudopodial passages through the shell, and more globular chambers, and these are set on in a somewhat heaped fashion, and but roughly spiral, so that in most cases the stolon-hole of each chamber comes near to the other apertures, and they all open into a kind of vestibule in the middle of the shell. These are the *Globigerinæ* (globe-bearer, Fig. 16_9). Some abound in the Chalk, while others are met with in the present seas and oceans. They may all be said to be of the same species as the common *Gl. bulloides*, figured and described by d'Orbigny. The form most common in the Chalk (*Gl. cretacea*) is the most truly spiral of all the varieties. The Adriatic yields a neat *Gl. bulloides*, which is also met with at many places in the great seas; and it lives and thrives in the abyssal depths of the ocean, attaining a relatively large size, and putting on coarse prickles and a much thicker shell than it has in shallow waters. On the surface of the ocean another variety is found floating; it is like *bulloides*, but with enormously long, hair-like prickles; these in life are invested with sarcode, which, on the outside, becomes coated with shell in *Orbulina* (globe).



Figs. 17–20.—FORAMINIFERAL SHELLS. (*After d'Orbigny.*)

17, Heterostegina depressa; 18, Amphistegina Lessonii; 19, Fabularia discolithus, one of the *Miliolidæ*; 20, Orbiculina numismalis, var. adunca.

Figs. 21–24.—FORAMINIFERAL SHELLS (*After d'Orbigny*), FIGURED WITH THE APERTURE DOWNWARDS.

21, 22, Glandulina lævigata, outside and section; 23, 24, Nodosaria lamellosa, outside and section.

The *Rotalia* (wheel, Figs. 16_{10}, 34) is a type, or leading form, among an immense series of more or less spiral Foraminifers, varying in their shell-structure plan of spire from nearly top-shaped to flat (with occasional loss of spire in either a cylindrical or a heaped growth), and the shape and position of aperture. *Pulvinulina* (cushion), *Discorbina* (basket?) *Planorbulina* (flat-circle, Fig. 29), and *Calcarina* (spur, Fig. 31), are other important members of the Rotaline group.

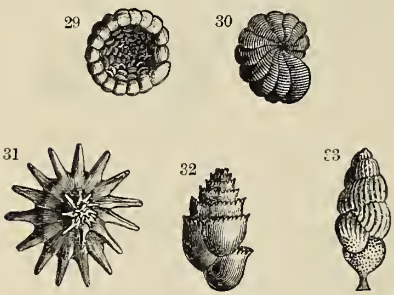
Under the heading *Nummulitidæ* are grouped some high-class Foraminifera, which, however, have their simple types among them and closely associated. Thus the little, thin, neat *Nonionina* (from "nonion," a fancy name) leads up, by more and more complex shell-structure to *Polystomella* (many-mouth); and the relatively simple *Operculina* (like the *operculum* of some gasteropods) is at the root not only of the greater and complex *Nummulites* (coin-like), but also of its congeners—on one hand, *Amphistegina* (double-stage, Fig. 18), and, on the other, the more cyclical *Heterostegina* (odd-stage, Fig. 17), with *Cycloclypeus* (circle-shield) and *Orbitoides* (circle-like). Most of the Nummulitids, except *Orbitoides*, occur abundantly in some sea or other. *Nummulites* is not rare, though small, in the Australian seas; but in the fossil state it constitutes masses of limestone, hundreds of feet thick, and hundreds of square miles in extent. Of these limestones many great

Figs. 25–28.—FORAMINIFERAL SHELLS (*After d'Orbigny*), FIGURED WITH THE APERTURE DOWNWARDS.

25, 26, Textularia aciculata, outside and section; 27, 28, Bigenerina (Textularia) nodosaria, outside and section.

buildings have been constructed—such as the Cathedral of Gerona and some of the Pyramids of Egypt. *Fusulina* (distaff) is a spindle-shaped Nummulitid forming masses of limestone of Carboniferous age in Russia and North America. This form, *Alveolina*, and *Loftusia*, resembling one another in shape, belong to quite different groups; an example of the imperfection of d'Orbigny's classification based on the shape of shell and setting on of the chambers.

In many of the Foraminifera, especially the *Porcellana*, the chamber-walls merely tent over the sarcode, whether thread-like, beaded, folded, or spiral; the edges of the new chamber resting on the surface either of the object to which the Foraminifer is attached, or on a former whorl of the shell. In more highly-developed *hyaline* species, each segment of sarcode becomes wholly coated with perforated shell-matter, except where it is attached by the stolon to the previous segment, and where it gives off a new bud. Further, the sarcode is thrown back over the already formed chambers more or less freely, and the test gets thickened, and sometimes ornamented with supplemental shell-growth. But a most important feature in the best kind of these shells (*Nummulites*, *Polystomella*, *Rotalia*, *Calcarina*, &c.) consists of a system of vessels, or canals, formed between the consecutive chambers of such well-coated kinds, and continued in a spiral manner along the upper and lower edges of the chambers, and communicating either directly with the surface (*Polystomella*), or through a reticulation of similar vessels in the thickened edge or "marginal cord" of the shell. These vascular portions have been termed the "intermediate skeleton," with its "canal-system," and evidently permit of free sarcodic communication between the early innermost segments and the outside (Fig. 34).



Figs. 29–33.—FORAMINIFERAL SHELLS. (*After d'Orbigny.*)

29, Planorbulina mediterranensis; 30, Peneroplis (Dendritina) arbuscula; 31, Calcarina Defrancii; 32, Bulimina marginata; 33, Uvigerina pygmæa. Figs. 32, 33 are figured with the aperture downwards.

It is very doubtful to some if the *Foraminifera* and the marine *Radiolaria* use their pseudopods for catching living prey; and it has been suggested that they obtain nourishment by absorption of nitrogenised aliment from the sea-water. The similarity, however, of their pseudopods with those of prey-catching *Reticularia* supports, by analogy, the idea that they take organic particles as food.

In some cases young Foraminifera, resembling what must have been the earliest stages (primordial segments) of the parent, have been found within the shell of an adult individual, and too large to escape by the stolonal aperture. The mother, then, would be at least partially burst for their escape. In other cases such a brood has been seen outside and around the mother, possibly having been emitted in an imperfect state. There seems to be no doubt that the sarcoblasts so often present, and looking like ovules, may be the sources of young broods. It has been remarked by Williamson that some twin monstrosities, as double Foraminifers, beginning in one primordial chamber, may indicate that "fission" is one method of reproduction with these creatures under some circumstances.

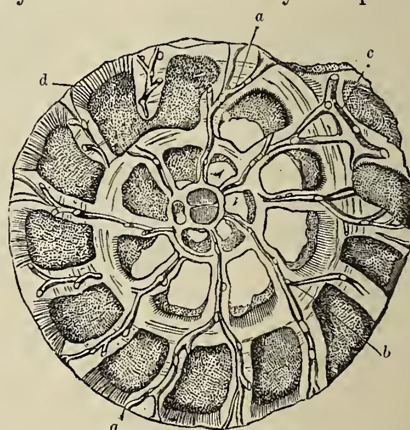


Fig. 34.—SECTION OF THE SHELL OF ROTALIA SCHRŒTERIANA, NEAR AND PARALLEL TO ITS BASE. (*After Williamson and Carpenter.*)

Showing—*a a*, the radiating interseptal canals; *b*, their internal bifurcations; *c*, a transverse branch; *d*, the tubiliferous wall of the chambers.

XLIX.—Many animalcules formerly classed among the *Infusoria* (which are an important group of the *Protozoa*), especially *Monas* and its allies, have of late years been recognised as belonging to a different protozoan group, more nearly allied to the Rhizopods, inasmuch as at some period of their existence they are in an Amœboid condition, if not living as actual *Amœbæ*. Their typical form is a nucleated corpuscle, with a vacuole, and an external thread-like appendage, or tail-like lash. Hence they have been grouped as the *Flagellata*.*

* Latin, *flagellum*, a little whip.

Such as these are associated together in groups, like colonies, on various plans; and the constituent members of the compound mass undergo changes leading to the production of new Amœboid and other forms. Such minute flagellate organisms, together with simple protoplasm, make up for the most part the living slime of Sponges.

There are also some small organisms, similar at one time of their developmental growth to little puff-balls and other fungi, and parasitic on plants and wood, which break up and allow innumerable spores to escape; and each of these gives rise to a flagellate Monad, with nucleus and contractile vesicle, and endowed with power of enclosing and feeding on organic atoms. These Monads, becoming Amœbas, join together, and form a large jelly-like mass ("plasmodium"), in which ultimately the fungoid organisms and their spores are developed in their turn. This general or common slime colony, in the meantime, pushes out pseudopods, moves on and on, engulfing food-particles, and, when extended to the utmost, becomes a coarse network, showing the usual circulation (*pseudo-cyclosis*, Wallich) of granules in the sarcode. These are the *Mycetozoa* alluded to above.* The *Labyrinthulea* is such a marine Protozoan. It forms groups of numerous yellowish nucleated corpuscles, usually spindle-shaped, but changeable, very loosely associated together in a net-like tissue, and gliding about within its substance. Some free Amœboids are given off at times by the tissue; but the tapering corpuscles by-and-by mass themselves in groups; these become encysted, and at last each corpuscle, or gelatinous cell, produces four young cells, or spores.

L.—The *Magosphæra*, a small spherical body rolling through the water (salt and fresh), consists of numerous vase-shaped nucleated corpuscles fitted together side by side, radiating from the centre, with six-sided outlines, the tapering ends inwards, whilst their outer ends have vibrating fringes, giving a hairy surface to the living ball. Its component cells break up and produce isolated swimming atoms, and these become creeping Amœboids. Each of these, in an encysted condition, divides again and again, until a new compound Magosphere is formed, which breaks the wall and escapes.

LI.—Another life-history of one of the *Protozoa*, although not that of one of the Rhizopods, is very interesting, and shows us how close is the relationship, and how narrow are the boundaries, between the Protista and the Protozoa proper, and between their several groups. The minute parasites found in the insides of worms and insects, and known as *Gregarinæ*, have been closely studied. In its advanced stage of growth a *Gregarina* consists of one, two, or three cell-like, nucleated corpuscles of contractile protoplasm, enclosed in a soft, smooth, elastic skin, sometimes furnished with hooks at one end. The "nucleus" is large, mostly round and clear, with a "nucleolus." By contractions of the sarcode just beneath the skin, the *Gregarina* moves creepingly along on the moist surfaces from which it absorbs its nutriment. Reproduction takes place either by division or by zoospores. The latter are produced after a "resting stage," when either a single individual, or several together, have become "encysted;" and, the nuclei disappearing, the sarcode has broken up into a great number of germinative cells, or spores, called Pseudo-naviculæ. From each of these an Amœboid or *Moneron* escapes, which becomes nucleated, and is transformed into an *Amœba;* and this, furnished with an envelope, lives as a *Gregarina.*

LII.—Like other very minute animalcules, mouthless, but otherwise resembling *Infusoria* to some extent, the exceedingly small moving bodies seen (with high microscopic power) in decomposing organic infusions of organic substances, and known as *Bacteria* and *Vibriones*, are grouped among the *Monera.* They look like delicate tremulous filaments, and may be straight, curved, or spiral, oscillating, vibrating, or undulating, and are often jointed, or partially divided in the process of being multiplied by "fission."

LIII.—One interesting fact is observable in the comparison of the life-history of Rhizopods with that of higher animals—even with the highest of the Vertebrata. The organic material which is their only living substance, excepting some occasional mechanical support derived from mineral matter, is really a most essential, if not, indeed, in some respects the most essential, substance in even our own bodily system. As the sensitive copper wire in the electric cable is the essential portion of that wonderful cord, so the delicate innermost protoplasmic core of our complex nerve-chord and nerve-threads is essential to the perfection of our nerve-system. In some of the lower animals,

* See also W. S. Kent, "Pop. Sci. Rev.," n.s., No. 18, 1881, p. 97, &c.

as Echinoderms, the nerves are nothing but protoplasmic threads. Impossible as it would be for highly organised animals to move and get their living without bones and muscles, yet without protoplasm, coating their stomachs and other organs, and floating in their blood, to carry on the work of preparing and distributing organic products to the well-being of the whole, they could not exist; and in the nerves protoplasm is the mysterious communicator of both functional activity and the over-ruling will.

LIV.—The Bibliography of the *Rhizopoda* is immense. Dr. Leidy (in his book often quoted) gives twenty-three quarto pages full of memoirs on the fresh-water forms ; but many of these refer also to marine Rhizopods of various kinds. For English readers, W. Archer, H. J. Carter, J. Leidy, and last, but not least, G. C. Wallich, have treated of Amœbans, Actinophryns, &c.; and among foreigners, Auerbach, Cienkowski, Claparède and Lachman, Dujardin, Ehrenberg, Greeff, Hertwig, Lesser, Perty, and Schulze. For *Radiolaria*, Ehrenberg, Haeckel, Wallich, and others. For *Foraminifera*, English students will find, among many others, Williamson, Carpenter, Carter, Parker, Jones, Siddall, and H. B. Brady; and among very many foreign naturalists Ehrenberg, Lamarck, d'Orbigny, von Reuss, Bornemann, Seguenza, Karrer, d'Archiac, and especially Max Schultze.

CLASSIFICATION OF THE RHIZOPODA. (*After Wallich.*)

RHIZOPODA.

- 1. Nucleus and Contractile Vesicle. PROTEINA.
  - Pseudopodia monomorphous (usually of one kind). *Actinophrys*, *Gromia*, *&c.*
  - Pseudopodia polymorphous. *Amœba*, *Difflugia*, *Arcella*, *&c.*
- 2. Nucleus; no Contractile Vesicle. PROTODERMATA. Skeleton Silicious.
  - Tubular. DICTYOCHIDÆ.
  - Solid. PLAGIACANTHIDÆ. ACANTHOMETRINA. THALASSICOLLINA.
- 3. No Nucleus; no Contractile Vesicle. HERPNEMATA.
  - Skeleton Silicious. POLYCISTINA.
  - Shell not Silicious (Chitinous or Calcareous). FORAMINIFERA.

T. RUPERT JONES.

TYPE PROTOZOA.—CLASS INFUSORIA (INFUSORY ANIMALCULES).

Microscopic Animals—One Cause of the Phosphorescence of the Sea and of the Discoloration of Water—The Life in Infusions—Characters of the Infusoria—Example of Ciliate Infusorians—The Slipper Animalcules—Their Construction—The Flagellate Order—Features—*Cercomonas*—The Cilio-flagellate Infusorians—Characters—The Animalcules of the Ponds in Phœnix Park, Dublin—*Melodinium*—*Ceratium*—The Order Tentaculifera—Characters—*Acineta*—Classification—The Ectoplasm—The Endoplasm—Origin of the Cilia, Flagella, and Tentacles—How Infusorians Feed—Action and Function of the Contractile Vesicle—The Nucleus or Endoplast—The Colours of Infusoria—The Coloration of Waters—Trichocysts—Reproduction by Fission, Gemmation, and otherwise—Distribution—TENTACULIFERA—SUCTORIA—ACTINARIA—CILIATA—HOLOTRICHA—Paramecium—Prorodontidæ—Trachelocercidæ—Ichthyophthiriidæ—Colepidæ—Ophryoglenidæ—Pleuronemidæ—Lembidæ—Family Discovered by Leidy—Opalinidæ—HETEROTRICHA—The Largest Infusoria—*Spirostomum ambiguum*—*Condylostoma patens*—*Stentor polymorphus*—PERITRICHA—*Halteria grandinella*—*Urocentrum turbo*—The "Bell" Animalcules—Genera with Vorticella-like Animalcules—HYPOTRICHA—CILIO-FLAGELLATA—FLAGELLATA—*Noctiluca miliaris.*

If a glass tumbler be dipped into a pond or ditch, so as to collect some of the vegetation which is found at the surface and at the sides, besides some clear water, it will invariably be found to contain numerous living things, some of which are just visible to the naked eye, whilst others require a lens or a compound microscope for their detection and examination.

The larger living things are mostly in rapid movement about the water, whilst some cling to the small plants and weed. They are usually small Crustacea, and also the larvæ and active nymphs of insects. Sometimes a water-spider is included in the capture, and frequently small worms are to be seen. Often just visible, and moving here and there, are numerous animals which evidently produce considerable currents in the water, and a lens enables the observer to distinguish that they belong to species of Rotifera of the Vermes.

But the most numerous of the dwellers in the water are either, in a few instances, just visible to the unassisted eye, or are to be seen in countless numbers with the aid of high magnifying powers under the compound microscope. Amœba and Gromia, minute Rhizopoda, may be found on the weed or on the glass which contains the water, and little moving things are visible which the botanists state are of the nature of vegetables, such, for instance, as the globe-like Volvox. But besides Crustacea, Insecta, Vermes, and Rhizopoda, and vegetable organisms, there are thousands of microscopic, or nearly microscopic, animals, which are called Animalculæ, or little animals, and also Infusoria, or animals which live in infusions. Suppose that some sea-water is collected, with a piece of seaweed in it; after a few days a host of those minute microscopic animals will be found in the slime around the weed.

Fig. 1.—INFUSORIA IN THE FIELD OF THE MICROSCOPE.

On a warm summer evening, as darkness closes in, the ripples of the sea become luminous, and flashes of light start from one part of the harbour or coast-line, and stretch far and wide, expanding in ever-widening circles. This particular form of phosphorescence of the sea is due to the presence of myriads of minute animals, which do not belong to any of the groups of animals hitherto described in this work, and which must be ranged amongst the Infusoria. Again, discoloration of fresh and salt water often occurs, and it is found to be produced by crowds of microscopic creatures. In water which is brackish, in water which contains a considerable quantity of salt, in water which may be icy cold or very warm, and in water which is impregnated with fœtid gas and decaying animal and vegetable remains, these simple, active, wandering, or sedentary microscopic creatures, which constitute the lowest forms in the animal kingdom, and which in some instances are separable only in a very arbitrary manner from the simplest and lowest members of the vegetable kingdom of nature, may be found in abundance. Place some of the pond water, deprived of its visibly living and moving things, under a microscope with a low power, or such an one as will magnify about forty times: minute bodies, hitherto invisible, are seen moving rapidly across the field of vision (Fig. 1), sometimes rushing across, so that only an indefinite idea can be gleaned of their shape; or

going along more slowly, either steadily or turning over from side to side, and screwing themselves, as it were, forwards. Sometimes a dozen or more will come within the range of vision, and twist and turn in every direction, and suddenly rush off, moving so as not to come in collision. Occasionally a globular-shaped thing will come by and stop, and just as suddenly will leap, as it were, in the water, and go right out of sight. Now and then a great current of water appears to be in motion, near the side of the field of vision, and if the slide holding the water be moved, so as to bring it beneath the eye, some balls, like specks, are seen united to delicate stems. They produce much movement in the water, and are suddenly dragged backwards towards their fixed point. Here and there, settled down and resting on a kind of stem, some pear-shaped things may be seen, with delicate hairs sticking out from their ends. A still higher power of the microscope, which will magnify from 300 to 1,000 times, enables other and smaller creatures to be seen, and renders the minute structures, of the larger, visible and capable of study. Amongst the smaller ones are little bag-shaped things, with one or two hair-like projections—the cilia which keep them in movement—and in places here and there are multitudes of little moving things, mere lines of matter, with an end produced into a hair-like tail or flagellum. These are amongst the simplest of living things, and may be animal or may belong to the lowest plants. The microscope reveals, amongst the larger kinds, that they move in consequence of the vibration, or to-and-fro movement of microscopic cilia, and that the kinds which are stalked can be retracted by the contraction of a granular tissue resembling the simplest form of muscle.

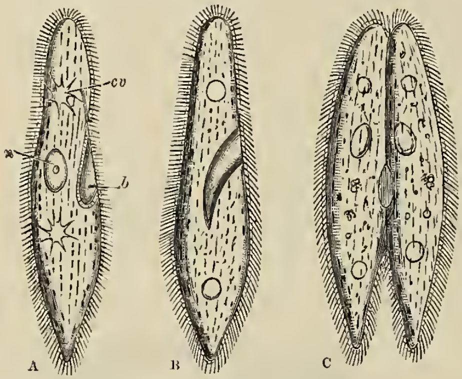


Fig. 2.—PARAMECIUM AURELIA.
A, Lateral, B, ventral surface; C, in conjugation; *cv*, contractile vesicle; *n*, nucleus; *b*, oral aperture.

If lately-collected rain-water is examined in the hope of discovering any of these minute forms of life, disappointment will occur. But if some hay, or any vegetable matter, be allowed to soak in pure water exposed to the air, or if pieces of flesh, brain, blood, or any animal substance, be placed in water, and also exposed for a day or two, a great many species of these animalcules, or Infusoria, the individuals being in vast multitudes, will be distinguishable. Certain kinds of these animalcules are almost invariably to be found in water in which particular vegetable or animal substances have been soaked, and a succession of kinds is often observed to occur as the infusion gets old. The free access of air is requisite for all this, and the hay and animal substances form the food of the minute creatures, whose derivation is not from the minute structures or broken-down tissues of the plant or animal. The air contains the extremely minute spores, or reproductive particles, whence the animalcules spring. There is no spontaneous generation of these animalcules, and no turning of dead animal or vegetable tissue into them. The term Infusoria, or animals of infusion, merely relates to where they are to be found in most instances, but not invariably, and it must be carefully noted that the animalcules are not derived from the infusions. Certain infusions suit particular kinds of Infusoria, and these particular species are to be found in them.

The Infusoria are exceedingly simple in their construction, may be said to be uni-cellular, and are allied, as Protozoa, to the Rhizopoda. There is this distinction, however, that whilst the majority of the Infusoria move actively, and a great number are sedentary, or move during some part of their life-cycle, they rarely have silicious or calcareous tests,* and the pseudopodia, which sometimes exist, never run together as they do in Gromia and Amœba amongst the Rhizopoda. The body is usually soft, and there are one or more contractile vesicles. A nucleus exists, and there are vacuoles which contain food. The outside of the body is ciliated in a great number, has but one or two long cilia in front in others, and one group has no cilia, but tubular processes project from the more or less pear-shaped body, and really act as suckers.

The following are examples of the four great divisions or orders of the Infusoria.

* Haeckel has described some with tests.

Pond water and artificial infusions of hay yield, as a rule, considerable numbers of a rather large animalcule, which may be from $\frac{1}{96}$th to $\frac{1}{120}$th of an inch in length. They are free swimmers and long-bodied, being narrowish and bluntly pointed at one end, and more sharply at the other. They are flat also, and there is a groove in the body extending from the left side of the front part of the body backward and underneath to about the middle. They are about four times as long as broad, and their shape has given them the name of Slipper animalcules (Fig. 2).* They are not quite symmetrical fore-and-aft, and the back and ventral surface can be distinguished. The whole of the body is covered with a fine down of cilia of nearly or quite equal size throughout, which vibrate with considerable rapidity, enabling the animal to move here and there rapidly, to turn round on its axis, to swim backwards and forwards, and even to turn like a screw on its long axis, throwing the under part up and over, to replace the back in its original position. As these animalcules, which have a yellowish-brown tint by transmitted light, move vigorously along, they rush over the field of the microscope and re-enter, and should there be a collection of vegetable mucus, numbers will come together and push in and amongst it, passing here and there, but never brushing up against one another, so as to come into collision. It is evident that they have some power of slightly altering the shape of the body, and that the slit on the underside has to do with the inception of food. The cilia, when the animal is moving or comparatively still, form currents in the water, and those in the neighbourhood of the slit produce whirlpools, down which rush minute particles of food. These pass down the slit, and enter the body at a kind of mouth, and they there come in contact with the soft inner substance composing the animalcule, and sink into it, being surrounded by a drop of water. Several of these morsels of food are to be seen lying in clear spaces filled with water or food vacuoles, and as the whole of the soft internal structure tends to move in an amœboid kind of manner, the vacuoles change their places. This gave rise to the false idea that the Infusoria were many-stomached, or "polygastrica." In this internal substance, or endoplasm, some other things are to be seen. Firstly, there is an oval body with a small dark spot in it, the nucleus or endoplast, and the nucleolus or endoplastule; secondly, there are two spots, one close to either end of the body, which gradually become more visible and transparent, and suddenly shut up and disappear. They are the contractile vesicles, and it is commonly observed that, if the animalcule is subjected to any pressure, these light spots present rays passing from them into the endoplasm, so as to assume a stellate appearance. The opening and closing of these vesicles are very regular. There is a most delicate tissue covering the whole animalcule, and another from which the cilia spring. They are elastic, and appear to be endoplasm in a less watery condition. They form the ectoplasm. Between these layers and the minutely-granular endoplasm is one of exceedingly delicate rod-like bodies arranged point outwards, and they are called trichocysts.

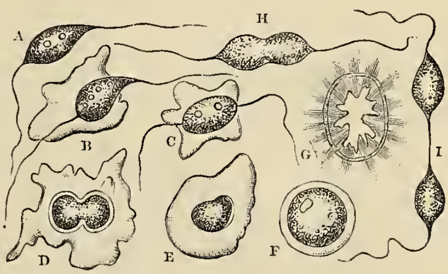


Fig. 3.—CERCOMONAS TYPICA. (*Saville Kent.*)
A, Adult; B—I, different stages in the development. (*After Dallinger and Drysdale.*)

The animalcule evidently respires through its outer ciliated coat, takes in food through the mouth at the bottom of the slit, has several food vacuoles, which finally come near the surface skin, and discharge the undigested matters. As the food, consisting of minute spores and animal and vegetable matters, is digested, the protoplasm of the body is added to, and the circulation and removal of effete matters are in relation to the contractile vesicles.

The creatures languish if the water remains too long without exposure to air, but otherwise their movement appears to be constant. Occasionally two will approach and cling together by their oral or ventral surfaces, and it is occasionally noticed that a large individual contracts midway and finally separates into two. If watch be kept long enough, the animalcules will be noticed to become quiet, to take on a globular form, and to have the ectoplasm dense and non-ciliated. Sooner or later the globe will burst, and a host of minute moving things will come forth, each of which is a young animalcule.

* *Paramecium aurelia.*

This is a common instance of the order of the class Infusoria, called, from the body being more or less covered with cilia, the INFUSORIA CILIATA.

The highest powers of the microscope, and glasses possessing very perfect defining qualities, are requisite in order that the next type of Infusoria may be seen perfectly. The little creatures are free swimming, and the body is long, egg-shaped more or less, but it has a projection so as to render it more or less spindle-shaped or fusiform. In front, there is a single filament prolonged from the body like a very large cilium, and a longer one, about twice the length of the body, projects behind. These are the flagella. There is a single minute contractile vessel in the body on one side, and the nucleus or endoplast is spherical, and near the centre of the animal. There is no mouth or special aperture for food, and there are no cilia on the soft external part, which barely differs from the inner mass of the minute body or endoplasm. Only measuring from $\frac{1}{2000}$th to $\frac{1}{3500}$th of an inch in length, these minute Infusoria are found in vegetable infusions. They swim freely by means of their long flagella, and also crawl over substances very much after the fashion of Amœbæ. It may happen that one may be seen larger or broader than the others, and, after a while, the observer is repaid by seeing the body

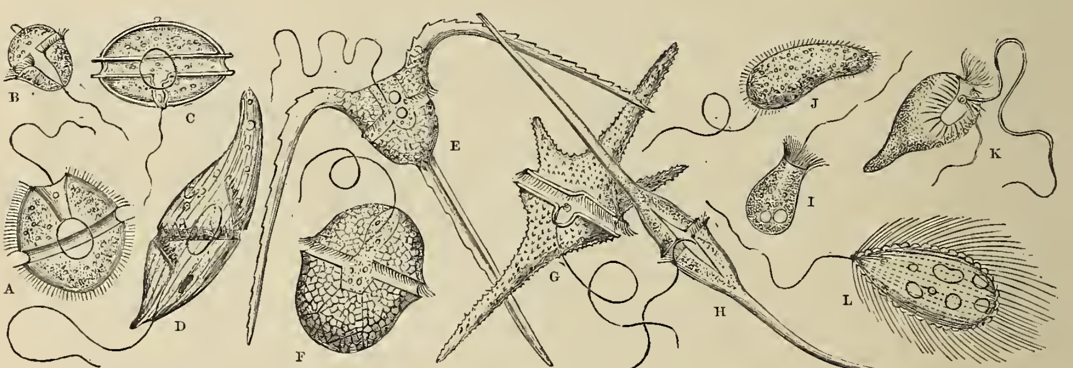


Fig. 4.—GENERA OF CILIO-FLAGELLATE INFUSORIA.

A, Melodinium uberrimum; B, Glenodinium acuminatum; C, Diplopsalis lenticula; D, Gymnodinium spirale; E, Ceratium tripos; F, Peridinium tabulatum; G, Ceratium longicorne; H, C. fusus; I, Stephanomonas locellus; J, Mitophora dubia; K, Heteromastix proteiformis; L, Mallomonas Plosslii.

split down its length, and two creatures swim off, each supplied with a front and rear flagellum. If two come in contact, they join together, like Amœba, and after a while the mass loses its flagella, and a vast number of spores are formed out of the endoplasm. These escape, and gradually form into creatures like those which produced them.

Exceedingly minute particles of food are taken in by the surface of the body at no particular spot, and the undigested matters simply pass through the endoplasm to the outside. This Infusorian is a Cercomonas* (Fig. 3), and is a fair example of the order called the FLAGELLATA. Members of this order are distinguishable—in some instances with difficulty—from moving spores of the lower plants, and indeed it is in this group that the junction of the animal and vegetable kingdoms is to be found. The Flagellata contain very simply-constituted organisms, and some which are less so, and of these last the phosphorescent marine Noctiluca is an example.

Another type of Infusoria combines, as it were, the characters of the ciliated animalcules and those which have a flagellum. The kinds which are associated with it are mostly found in sea water, and in many parts of the globe. A few, however, are to be noticed in fresh water in the United Kingdom. Thus, Professor Allman found enormous multitudes of an Infusorian about $\frac{1}{500}$th to $\frac{1}{1000}$th of an inch long, of a reddish-brown colour, in the ponds in Phœnix Park, Dublin. It had an almost globular body, with a constriction or furrow running round the middle, and a groove passing from this furrow over the body to the top. The whole surface was covered with extremely delicate moving cilia, and a long, slender, active cilium or flagellum was found to be placed on the top in the groove. A large endoplast (nucleus) was in the centre of the animal, and just below the origin of the flagellum was a small, intensely red spot. A contractile vesicle occurs in this type. The brown colour of the ponds in

* *Cercomonas typica.*

1854 was owing to the presence of prodigious numbers of this species of Melodinium* (Fig. 4, A). The tint was sometimes uniformly diffused through the water, and at others was collected in dense clouds, varying from a few to upwards of 100 square yards in extent. Later on, the coloration of the ponds, brought about by the agency of these minute organisms, had much increased in density. By the 9th of July the water was so dark and brown, that a white disc, half an inch in diameter, was invisible when plunged to a depth of from three to six inches; while a copious exit stream, constantly flowing away from the ponds, presented a similar deep brown hue. In many places the animalcules had descended from the surface, and were found congregated in immense masses near the bottom of the water. In these instances they had, for the most part, become quiet; the flagellum and cilia had disappeared, and a kind of transparent tissue had been developed around each one. During the life of these curious animalcules the body divides across, and two individuals are formed; and this proceeds time after time, adding rapidly to the numbers of individuals. Moreover, the encysted state is accompanied by a breaking-up of the internal protoplasm or endoplasm into numberless particles, each of which will grow into a form resembling the parent.

In examining the phosphorescence of the sea, moderately large animalcules of $\frac{1}{90}$th of an inch long are occasionally seen. They are light-emitting, of a yellow colour, and have a remarkable shape and construction. An external coat, transparent but hard, exists, and it covers the soft structures. It is prolonged into a long horn in front and behind, and the body is nearly globular, with a depression around it, and a groove crossing this at right angles. The appearance is very peculiar. Cilia bound the depression, and a very long and delicate flagellum, which moves like the lash of a whip, starts from the groove. The long fore-and-aft projections are quite stiff, and the only mobile parts are the cilia and flagellum. This Infusorian belongs to the same order as the last, and to the genus Ceratium† (Fig. 4, H). They are CILIO-FLAGELLATA.

A very different kind of animalcule must be taken as the example of the next and last order of the Infusoria. If the surface of water-plants in the Birmingham and Stratford Canal, for instance, be observed, a fine Infusorian $\frac{1}{75}$th to $\frac{1}{100}$th of an inch in length may be seen fixed on a long stalk which is straight and stiff. The body, placed at the top, is contained in a cup-like sheath, with a triangular outline, widest where free, and where there is a slit which enables the endoplasm to communicate with the water outside. The endoplasm (finely granular) does not fill the cup, but collects in an egg-shaped mass which has a contractile vesicle, and the nucleus or endoplast is in the form of a band. There are neither cilia nor a flagellum, but a bundle of numerous tentacles exists at both ends of the free end of the cup-shaped sheath, and they are processes of the body. The tentacles have a disc-like top, and do not move so as to enable the animal to swim. They are catchers of prey, and any small animalcule coming in contact with them is stopped, and its delicate tissue is penetrated by their sucker-like disc (Fig. 5)‡. By-and-by the endoplasm of the victim is sucked out of it, and acts as the food of the catcher. The young of these stationary Infusorians are active, and move well and rapidly with the aid of cilia, and thus resemble the Ciliate Infusoria. These Infusoria constitute the order TENTACULIFERA.

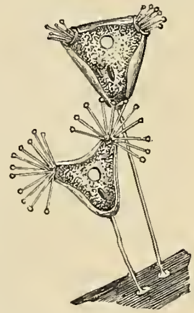


Fig. 5.—ACINETA TUBEROSA, WITH TENTACLES EXPANDED AND CONTRACTED.

There are, then, four great groups or orders of Infusoria typified by the species of the genus Paramecium, Cercomonas, Melodinium, and Acineta, and they constitute the orders Ciliata, Flagellata, Cilio-flagellata, and Tentaculifera.

A host of species, included in numerous genera, is classified under each of these orders, and there is the greatest diversity of shape and of method of life amongst them; but the main features and especial characters of the orders are so definite, that there is no difficulty in classifying any Infusorian, which has attained adult age, in its proper group.

From their great vivacity of movement, their many varieties of cilia, the invariable existence of contractile vesicles, and endoplasts, and sometimes trichocysts, the Ciliata, or the Infusoria which move by and are more or less covered with cilia, strike the observer as of predominant zoological importance. They are clearly more highly organised than the Infusoria which have only flagella. And these last appear to be lower in the animal scale than the creatures which have a few cilia,

* *Melon*, a peach; *dine*, a vortex. † *Ceratium fusus*. ‡ *Acineta tuberosa* (Ehrenberg).

and a flagellum also. The fact that the Tentaculifera are totally unlike the other Infusoria in their adult age is very remarkable; but it is evident that before they attain maturity they resemble the Ciliata. New structures are thus, by evolution, given to the Tentaculifera, and they have considerable affinities with the Rhizopoda. Their adult form is in advance of the ciliate young one, and the order Tentaculifera must stand at the head of the Infusoria. Next come the Ciliata, then the Cilio-flagellata, and, finally, the Flagellata.

Fig. 6.—DENDROSOMA RADIANS. (*After Saville Kent.*)
a, Embryos escaping with cilia; *b*, buds producing embryos like the parent; *st*, stolon.

The Infusoria are uni-cellular, and this is true where there are two or more individuals in close contact, or where a common stem supports the bodies of others, which may be numerous. For in these instances subdivision of the parent has produced the independent creatures. In the Tentaculifera, however, the most highly-organised amongst the Infusoria, in the species called *Dendrosoma radians* (Fig. 6), there is a root common to many trunks which give origin to branchlets terminating in a bundle of tentacles with suckers. This arrangement can hardly be called uni-cellular; there is, however, no actual cell division, and indeed the ordinary idea of the single cell is hardly applicable to this and many other Infusoria.

The simplest Infusoria belonging to the Flagellata, which have no special spot for the ingestion of food,* have no distinct environing membrane over their soft finely granular protoplasm, and they can assume various shapes for a while. Others belonging to the same group have the outside of the body slightly more solid than the rest. In the Ciliata the presence of an outer membrane is evident, and it is possible to distinguish, on some of them, four layers around the soft semi-fluid central endoplasm. On the outside is a perfectly transparent structureless membrane, and it is a true cuticle. It forms a sheath for the stalk of some Infusorians, and the covers or shields (*lorica*) of others (Fig. 7). It is composed of formed material, and is independent of the nutrition of the animal Under the hyaline outer layer there is, without exception amongst the Ciliata, a firm homogeneous elastic and contractile layer, of which the cilia and their various modifications are the offshoots. They penetrate the outer layer and arise from this inner one. In some, but not all, of the Ciliata, there is a layer beneath this last one, which is more or less fibrillar, and highly contractile. It is the muscular, or myophan layer of Haeckel. In the genus Stentor (p. 367) it is highly developed, and it can be seen, by using high and well-defining powers, in the common Vorticella, in which it forms the central, or contractile, part of the stalk, and a thin layer continuous with this is in the body. The fourth layer is not invariably found, but it has been already noticed in the description of a Paramecium. It produces and holds in place the minute rod-like bodies called trichocysts, which will be noticed farther on. These layers constitute the ectoplasm.


Fig. 7.—TINTINNUS LAGENULA, SHOWING THE LORICA AND THE CROWN OF CILIA.

The endoplasm, situated within the ectoplastic or outer layers, is more or less fluid, granular, and coloured glairy protoplasm. It is tolerably immobile in many Infusoria. In most it is subject to amœboid movements, to a faintly-developed rotatory movement, and to what may be called streaming. In some instances the movement is strong, and resembles that of the cyclosis of plants, as in Vallisneria and Chara. Noctiluca, the phosphorescent flagellate Infusorian, has the endoplasm more or less in the form of a network, with vacuole spaces, and a quantity of granular substance, and this condition is seen in other forms.

* Group *Pantostomata*

The spaces occasionally seen in the endoplasm, and which transmit light more readily than the rest, are called vacuoles; they may exist as spaces filled with water, and usually they contain, besides the water, a greater or less portion of the vegetable or animal matter which has been introduced into the body as food. They must not be confounded with the contractile vesicle. Besides these, there is the nucleus or endoplast, which is surrounded, in part, by the granular semi-fluid endoplasm, and which is also in contact with the deeper layers of the ectoplasm. Colouring matter, diffused or localised, is seen in the endoplasm, and this inner protoplasm produces the minute particles or spores which escape and develop into new individuals.

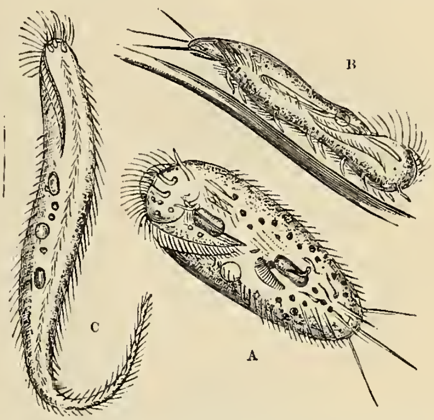


Fig. 8.—A, B, STYLONYCHIA MYTILUS, SHOWING CILIA, STYLES, AND UNCINI; C, EUROLEPTUS. (*After Stein.*)

In all Infusoria, the cilia and their varieties, the flagella and the tentacles are extensions of the substance of the body. In the minute flagellate animalcules the flagellum, which is an elongated whip-like cilium, is an extension of the delicate ectoderm: in the Ciliata the cilia arise from the special layer beneath the hyaline cuticle; and the long suckers of the Tentaculate order are probably extensions of the same tissue. The cilia differing in dimensions and shape in some Infusoria are the minute hair or eyelash-looking vibratile appendages which mainly move their possessors, or produce currents in the water when the Infusorian is fixed. They appear to move actively in one direction, and to return to their original position by their elasticity. The tops move forwards and backwards, and it is noticed in certain species that the ciliary lashing is consecutive in a series, and that it produces the appearance of rotation, as in the Rotifera (pp. 245–9). They are semi-solid and elastic, and they are moved by the contraction of the endoplasm at their base. The vibratile cilia are arranged in bands only, in certain families, and universally in others. Some Infusoria have some cilia which are elongate, flexible, but not movable, and they are then called setæ; and in one interesting genus (*Halteria*) these long hairs are utilised when the animal makes its sudden jumps. Some Ciliate Infusoria have these setæ stout, and placed on the ventral, or under-surface of the body, or at the extreme ends, and then they are called styles. In some instances the ends of the styles are branched or feathered. In a family of the Ciliata, the Oxytrichidæ (p. 371), there are claw or sickle-shaped appendages, which are modified setæ, called hooks, or uncini, and some of the species carry all these remarkable outer structures for the purposes of locomotion and prehension (Fig. 8). The body is, in some Infusoria, furnished with fin-like, thin, vibratile membranous fringes (Fig. 9), and in one important group of the Flagellata the collar of the animalcule, which exactly resembles that of the cell of the sponge, has its protoplasm in streaming movement, which carries the particles coming in contact with the outside over the top to the mouth within. The tentacles of the Tentaculifera resemble the pseudopodia of Rhizopods more or less; some have a disc-shaped sucker at the top, and are hollow, being filled with semi-fluid endoplasm. A spiral fibre is seen on the outside of some tentacles, and in one family there are no terminal suckers.

Whilst some Infusoria take in food at any part of their body, the morsel simply sinking into the soft protoplasm, and carrying with it a small quantity of water, forming thus a vacuole, in others it is carried in the direction of a particular orifice, slit, or tubular cavity, by currents in the water produced by certain cilia. In some species the mouth-opening is always visible, in others it is small, and only visible at the time of the capture of prey, and in a few it is so large that a morsel is often swallowed nearly as large as the captor. The mouth, in the most perfect forms, consists of a passage in the ectoplasm structures, which can dilate, and the lining of which is plaited, folded, and even furnished with a layer of rod-like teeth (Fig. 10). This part is often capable of protrusion, and on opening it leads to the exposed semi-fluid endoplasm, and not to anything like an œsophagus and stomach. The morsel simply sinks into the mass with a little water, and forms a vacuole.

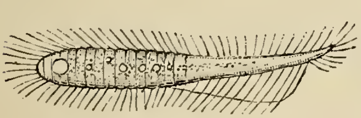


Fig. 9.—LEMBUS VELIFER.

One or more food vacuoles may exist, and as one is formed subsequently to the other, the oldest vacuole is the most deeply imbedded, and if the animalcule be fed with carmine, a number will be noticed forming a series in the endoplasm, and moving with it. Much of the food thus received is digested, and the rest is evacuated in a definite direction, and sometimes through a special opening in the ectoplasm—the anus. In many species, however, the fæcal matters pass out at any point.

When one of the Infusoria is lively and feeding, and is being examined under high powers of the microscope, one or more spots, with a circular or radiating outline, will suddenly appear near the ends of the body. Each begins in a point of greater transparency than the body structure all around it, increases rapidly in diameter, and often assumes a tinge of colour, retaining, however, its transparency. It is a light-transmitting space, with the slightly denser structure of the inside of the animal around it. As the light from the reflecting mirror of the microscope traverses the tissue of the Infusorian at this now enlarged spot, it seems to be unsteady, and this depends upon water passing into this really globular space, which, seen under the microscope, presents the appearance of a circular area (Fig. 11, A, *cv*). It is evident that water flows into this space, which is situated really in the layer immediately over the soft endoplasm; there is no environing membrane to it. Suddenly the circle of light closes in on its centre, and the appearance of a light point amongst the darker surrounding matter suddenly ceases. The tissue closes in on the space, moving in on all sides, and this is done not passively but actively, for in some instances a tremor can be seen to occur over the whole animalcule at the time of the contraction of the space. Moreover, although the space enlarges slowly, it contracts very rapidly, as a rule. If the Infusorian be kept for some time under observation, the absence of food and fresh water will begin to diminish its energies, and it will especially influence the rapidity of the dilatation and subsequent contractions of this space, which is termed a contractile vesicle. The appearance of the light spot is not so frequent; it commences languidly, and enlarges slowly, and finally contracts, or disappears less abruptly than in the instance of the vigorous animal. After a while, the appearance and disappearance of the spot—or, in other words, the dilatation and contraction of the contractile vesicle—become slower and irregular, and they cease with the death of the animal.

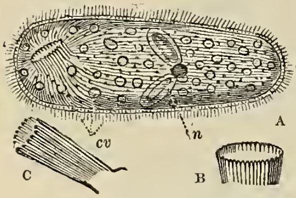


Fig. 10.—A, PRORODON MARGARITIFER; B, PHARYNGEAL ROD-FASCICLE OF P. NIVEUS C, DITTO OF NASSULA.

cv, contractile vesicle; *n*, nucleus.

More than one contractile vesicle may exist in the same species, and their position in the body, although generally well defined, is not invariably in the same spot. Usually, the vesicles are nearer the ends of the body than the central part, and when they are fully dilated they occupy not only a portion of the body hitherto filled with endoplasm, but come close under the outer and denser tissue. In the instances where the contractile vesicle presents the appearance, under the microscope, of a circular space, no movement can be seen, in the vast majority of observations, to extend from it into the endoplasm during the active contraction or dilatation. The water contained in the vesicle must go somewhere, and must be derived either from within the body or from without, or perhaps from both directions. Occasionally, however, a very indistinct movement can be seen radiating, as it were, amongst the granular, or almost homogeneous protoplasm of the animal, subsequent to an active contraction of the space. No visible movement accompanies the infilling. There are many Infusoria, such as the species of Paramecium, in which the contractile vesicle, when fully expanded, is not limited

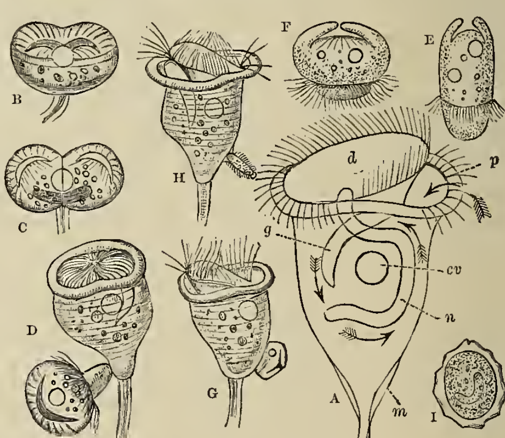


Fig. 11.—A, DIAGRAM OF VORTICELLA NEBULIFERA; B–D, PHASES OF LONGITUDINAL FISSION; E–F, PHASES OF ATTACHMENT, AND G–H, OF INCORPORATION OF FREE EMBRYO OF V. MARINA (*After Greeffe*); I, ENCYSTED STAGE OF V. MICROSTOMA.

d, disc; *p*, peristome; *g*, gullet; *cv*, contractile vesicle; *n*, nucleus; *m*, muscular coat. The arrows denote the course of circulation of food particles.

by a definite circle of endoplasm, but has rays, or tubular passages, tapering outwards around it (Fig. 2, *cv*). The passages are numerous, and may be seen to ramify at their extreme ends, and they are weak spots in the cortical layer over the more fluid endoplasm, extending far and wide from the vesicle. These passages transmit light more readily than the protoplasm in which they are placed, and it therefore occurs that, as water fills them, and they increase in diameter and length, they are nearly as light-transmitting as the main space with which they are continuous. They become largest just before the contraction of the vesicle, and they sometimes do not disappear until after its contraction. It is evident that the watery contents of the passages are pressed upon by the contraction of the surrounding protoplasm, and that this water and that of the space penetrate, during contraction, into this environing substance. Movement may be noticed under the outer tissue, here and there, within and along the lines of the passages. More or less defined communications exist between the outside water and the contractile vesicles through the ectoplasm, and the vesicle receives pure water from without, and collects and expels the impure water from within the animal. It is evident that the function of the contractile vesicle is of great importance to the animal, and it may relate to the elimination or removal of certain soluble matters resembling the urinary secretions. It may also relate to an internal circulation of water.

The rhythm of the dilatation and contraction is very remarkable, and Saville Kent states that "the time occupied between the consecutive pulsations of this organ is found, under normal conditions, to present a constant average among individuals of the same species, varying from a few seconds only in certain forms, to over sixty or even one hundred seconds in other types."

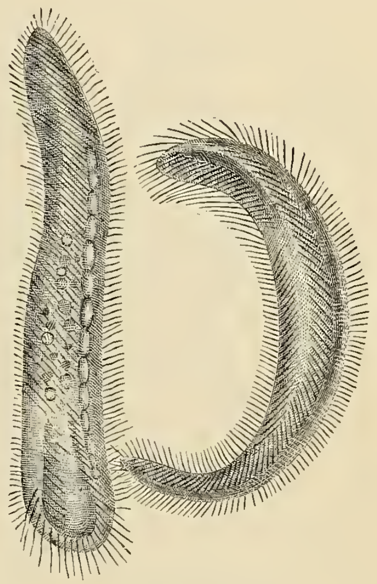


Fig. 12.—CONDYLOSTOMA PATENS, SHOWING MONILIFORM ENDOPLAST.

The nucleus or endoplast with its contents resembles, in some Infusoria, that of the simplest vegetable cell. In its simplest form, noticed in some of the Flagellata, the endoplast is more or less spheroidal, and may or may not contain a nucleolus or endoplastule. Saville Kent has given an admirable *résumé* of the knowledge which has been accumulating regarding these structures, and he notices that the first step towards complexity is in the genus Euglena and its allies, in which the endoplast becomes ovate in outline. A sausage shape is assumed in some Ciliata, and its ribbon shape in Vorticella has long been known. In some of the Tentaculifera the nucleus is branched, and in some Ciliata, such as *Condylostoma patens* (Fig. 12), it presents a necklace appearance, and in others the swellings are widely separated by narrow processes. More than one endoplast exists in the Oxytrichidæ, one being in front and the other behind the centre of the body; and in some species of Opalina the endoplasts are numerous. In its more complex forms the endoplast is enclosed within a very delicate transparent membrane. The nucleolus or endoplastule is sunken within the substance of the endoplast in some forms; it is attached to the inside of the membrane of the endoplast in others, and on the outside in a few Infusoria.

Two or three endoplastules exist in some, and in Vorticella they are granular fragments, one or more of which become enclosed within each of the segmental portions into which the endoplast becomes separated, during the process of internal budding, which will be noticed farther on. The endoplast is in contact with the softer internal substance of the Infusoria (the endoplasm), and also with the inner part of the cortical structures or ectoplasm.

The Infusoria are usually more or less coloured, and the Flagellata, with rare exceptions, have a small brilliant crimson spot at one end of the body; in one genus there are two of the spots. Amongst the Ciliata the red spot is rarely seen, and one genus has a black one; but the Tentaculifera do not have these pigment spots. Formerly they were considered to have to do with vision, but this is an error, and the common term "eye spot," is therefore incorrect. Diffused colouring matter tints

most Infusoria, and the smallest animalcules or monads belonging to the Flagellata have a pale glaucous or fluorescent hue, and Saville Kent notices that this is visible under high magnifying powers. It is probably due to reflected and not to transmitted light. Most of the Flagellata are coloured, and the species of one great group, the Euglenidæ, are of a brilliant green, the colour being diffused in the endoplasm. The colour is identical with that of the lower plants, containing chlorophyll, and it is remarkable that this green tint should turn to red. Thus in *Astasia sanguinea* the green colour, which gives a tint to the water in which the myriads of the animalcules swim, is suddenly turned to red, accounting for old and new traditions regarding the turning of fresh waters into blood. Ray Lankester has shown that in the genus Stentor the green matter, like that of *Hydra viridis* and *Spongilla*, is a chlorophylloid substance similar to that of plants. One Stentor, however, has a blue colouring matter which is produced by a special chemical combination called Stentorin. Quite as many Infusoria have a diffused pale amber to deep olive colour as green, and most of the Tentaculifera and Cilio-flagellata have these dull colours.

Saville Kent notices that some of the Flagellata differ from the majority by the presence of the olive colouring on two lateral bands on the body. In the Ciliata, a Leucophrys is of a brilliant crimson colour, and a Nassula has numerous violet granules in its endoplasm. Minute crimson granules have also been noticed in the contractile tissue of the stalk of Vorticella.

In some Euglenidæ, there are bodies in the green endoplasm which are of a starchy nature. Finally, there are the accessory structures of the cortical part of some of the Infusoria or the trichocysts. As has been already noticed (p. 355), they are visible in *Paramecium aurelia*, in the form of very slender rods crowded together in a layer, their points looking outwards beneath the outer cuticle. Under the action of weak acetic acid, these trichocysts force through the cuticle and beyond the cilia. Ellis, an Englishman, writing more than a century since, discovered these curious bodies; and Allman, in 1855, established their true nature, and assimilated it to a certain extent with that of the nematocysts of the Corals. But there are essential distinctions. Allman found that the minute fusiform rods, under external irritation, become suddenly transformed into long hair-like filaments, which projected from the whole surface. By carefully crushing examples, and isolating the trichocysts in their unaltered condition and in their fusiform shape (that is, swollen in the middle, and narrow at each end), it was found that after a few seconds the shape was altered with a jerk, as if some previous state of tension were relieved. A spheroidal shape was assumed by the hitherto fusiform rod. Then, in a few seconds, a spiral filament was observed to become rapidly evolved from the sphere, apparently through the rupture of a previously confining membrane. The spiral fibre unwound, and became straight and rigid. In their most extended state, these bodies were found to consist of a long rigid spiculum-like half, sharp at one end, and continued at the other into a very filiform part, which is bent more or less. Probably they have a noxious influence on minute living things.

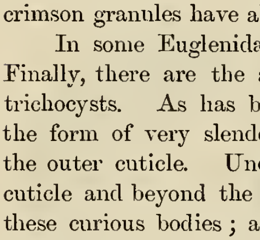


Fig 13.—COLEPS HIRTUS. (*After S. Kent.*)
A, Showing ornamentation; B, transverse fission.

Some Infusoria appear to retain the same shape under all kinds of circumstances; others enlarge laterally or longitudinally, and even twist, as they move here and there or endeavour to get in between substances, but they speedily return to their normal figure. Such irregular changes of shape as are seen in the Amœboids are not often found in the Infusoria, but a very different appearance is presented by some during active motion and feeding and during quiescence.

Nothing is more common than to see many Ciliated Infusoria moving along with the shape of their bodies altered by the presence of a greater or less central constriction, and if one of them is watched, it will be seen to separate, into a front and a hinder part, and each will become a separate individual (Fig. 13). Division also occurs lengthwise. It has been computed that, in the instance of *Stylonychia mytilus* (p. 371), no less than a million of independent beings were derived from repeated fission of a single individual in the course of ten days. When Infusoria form colonies, they arise from the repeated binary subdivision of the first stock, and in some instances masses result, slime-like, many feet in extent (*Epistylis grandis*, p. 370). In the majority of species, the division is across the body, and in others in a longitudinal direction, especially in the

Vorticellidæ. In the Stentors and some other genera the fission is oblique. The endoplast divides in every instance, and part remains with each individual, and the other organs, such as the mouth, anus, and contractile vesicle, are developed where they are wanting.

Some Infusoria increase by a process resembling budding, and in this process, the important endoplast contributes a little process which accompanies the protrusion of the body membrane to form the bud. In Noctiluca (p. 374) the protoplasm beneath the cuticle becomes broken up into nodular fragments, which are protruded upon the external surface, and are finally liberated as very minute bodies resembling monads, and these grow into adult Noctilucæ.

In some instances the young grow within the body of the parent, but only at the expense of the endoplast. Portions of this separate and become embryos, which escape with their cilia, and either resemble the parent or grow into its shape as in the Tentaculifera.

Another method of reproduction is when the Infusoria become quiescent; a delicate covering is then formed over the body, and the quiet and encysted creatures have their internal tissue broken up into myriads of minute particles, which escape, and finally assume the shape and destiny of the parent. It is found that sometimes an intermediate amœbiform condition occurs (Fig. 14).

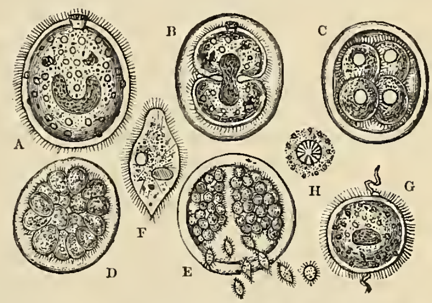


Fig. 14.—ICHTHYOPHTHIRIUS MULTIFILIIS. (*After Fouquet.*)
A, Adult; B–G, different stages of development (E, escape of young); H, oral apparatus.

Infusoria also reproduce after a process which somewhat resembles the conjugation in Algæ amongst plants. Swimming, or fixed by a common stalk, two animalcules come in contact by their oral surfaces, and remain united for a limited period. They swim about, and exist as one, and in the Flagellata the flagella are withdrawn, and amœbiform processes are cast forth. In other instances the junction of different individuals, one often larger than the other, persists. Under both circumstances the reproductive energy of the couple is intensified. How, is a matter of debate, but late microscopical researches by Bütschli and Englemann show that during the process the original endoplast in both animalcules breaks up into a number of fragmentary portions, and becomes lost among the endoplasm. By-and-by a new endoplast is constructed through the gradual assemblage and union with each other of fragmentary particles, and the new endoplast is common to both of the animalcules when the conjugation is complete and lasting, as in Vorticella (Fig. 11); while two or more, according to the normal number, are reproduced where the conjugation is transient as in Paramecium (Fig. 2). Bütschli denies that embryos are subsequently developed from the endoplasts, and he considers that the conjugation is a mere vital stimulant to the decaying energies of the animalcule. Before passing on to a short classification of the Infusoria, it is necessary to mention that they have a most extraordinary distribution. Some families inhabit salt water, others fresh; some species live in running water, others in stagnant pools. Many species are parasitic on, and others within, other Infusoria, and many groups of Invertebrata and Vertebrata. Many are only found in animal, others in vegetable, infusions. One group is mouthless and essentially endoparasitic. The Opalinidæ inhabit the alimentary canals of insects, frogs, toads, and the aquatic Annelida. Some Ciliata inhabit the stomachs of ruminants, some live in the human gut. Others live fixed to fish, or crawl about the Hydra. The Flagellata are found in fresh and salt water, and are often parasitic, and some inhabit human urine. In searching for ordinary and well-known forms, the surface of pure and coloured fresh waters, and the leaves of the plants, should be examined, and the waters of bogs and the sea-shore yield many new forms. The artificial production of Infusoria, by infusing hay, meat, &c., depends on the existence of the germs in the air, in the water, and collected about the plants.

ORDER TENTACULIFERA (*Huxley*).

An example of this order has been noticed already, and it explains the characters of the group. They are animalcules inhabiting either salt or fresh water, and many are parasitic on and within other

Invertebrata. They have tentacle-like processes, derived from the cuticle or from the endoplasm, or from both of these parts. The body contains an endoplast and one or more contractile vesicles. They increase by division across or longitudinally, and also by budding, which may be external or internal. Some of the young (embryos), on escaping from the parent, are ciliated, and the cilia may be arranged over the whole body, or in the form of a wreath around the body, or only on the under surface. With growth the state changes, and the cilia are lost. Others resemble the parent. The adults have neither cilia nor flagella. The majority of species are sedentary. The Tentaculifera are divided into two sub-orders, in one (the Suctoria) the tentacles are wholly or partially suctorial in their office, and in the other (the Actinaria) they are not suctorial but merely adhesive. One family of the first sub-order has one or two tentacles only, and another (the Acineta) has many tentacles, and some of the genera have the body without, and others with a lorica or a more or less covering sheath. *Acineta tuberosa* has the tentacles in bundles, which protrude through the transparent lorica, and the endoplasm can be seen within. It is a salt water form, and measures from $\frac{1}{300}$th to $\frac{1}{500}$th of an inch in length (Fig. 5).

These animalcules remain with their tentacles extended, and other freely-swimming minute Infusoria are stopped by the suckers at their tips. The endoplasm of the victim passes into the hollow of the tentacle and mixes with the soft tissue of the body of the Acineta. A third family includes the genus Dendrocometes, which settles on *Gammarus pulex*, and has rather flexible tentacles slightly branched at their extremities. Its embryos, which escape from the parent, are ciliated underneath only. The next family includes branching Acinetans, with many tentacles, a host of individuals apparently arising from a common stem. But the tops of the ramified stem are really not separate individuals, and the whole mass must be looked upon as one (Fig. 6).

Some embryos with tentacles are produced from the ends of stems (Fig. 6, *b*), and those which are ciliated are derived from the thicker parts of the stem (Fig. 6, *a*).

The endoplast is ribbon-like, and is much contorted in the stolon and band parts of the main stem, and is continued as a band into the branchlets.

The next sub-order (the Actinaria) have the tentacles simple or ray-like, as in the family Ephalotidæ, or represented by one or more retractile organs, which resemble a proboscis with or without cirri. The genus Ophryodendron (Fig. 15) is the type of the last, and the species are very extraordinary looking things. The animalcules may be solitary or in a little group, and then one has a long proboscis, and the others are more or less vermiform or flask-shaped, with a delicate tubular ending. The prey is caught on the proboscis, and gradually withdrawn into the body. They inhabit salt water, or fix on to the polyparies of Hydrozoa, or on to Crustacea. The embryos are ciliated.

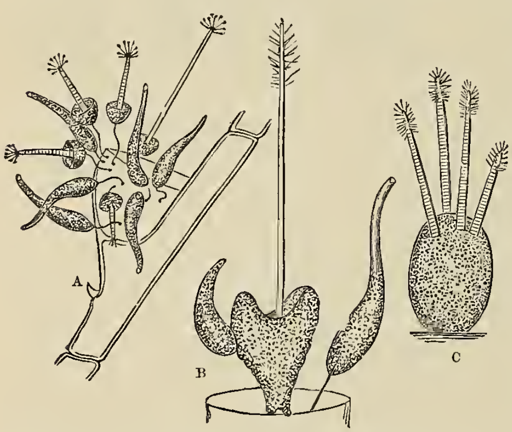


Fig. 15.—A, OPHRYODENDRON PEDICELLATUM ON A PLUMULARIA STEM (THE ELONGATE FORMS ARE THE VERMIFORM BODIES); B, MORE HIGHLY MAGNIFIED; C, O. MULTICAPITATUM. (*After Saville Kent.*)

ORDER CILIATA.

In this order the animalcules are more or less covered with vibratile cilia, some of which may be modified into setæ, styles, and hooks or uncini. A well-developed oral and anal aperture is mostly present.

The example (*Paramecium aurelia*) already given of this order brings these important characters before the mind. The order is divided into four sub-orders, of which the first is the Holotricha, or the Animalcules, which are closely covered all over with cilia, and usually furnished with trichocysts. Paramecium is the example of the first family of the sub-order (Fig. 2).

The Prorodontidæ are the second family, and they are ovate or cylindrical, and the oral aperture is at one end or at the side. The canal (pharynx) leading from the mouth to the endoplasm is bounded by rod-like teeth, which are well seen in the genus Prorodon (Fig. 10).

The species *Enchelys farcimen*, which is found in stagnant water, and is from $\frac{1}{430}$th to $\frac{1}{1000}$th of an inch in length, has the oral cilia larger than the others, and the cuticle of the bag-shaped body and changeable-shaped body is soft (Fig. 16).

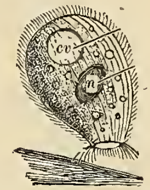


Fig. 16.—ENCHELYS FARCIMEN.
cv. Contractile vesicle; *n*, nucleus or endoplast.

The flask-shaped, long-necked forms, with cilia over the whole body, and the mouth at the end, constitute the family Trachelocercidæ. *Trachelocerca olor* has a body $\frac{1}{140}$th of an inch in length, and lives in pond water. Its long neck and body obliquely striated with cilia, the several contractile vesicles, and its double endoplast, are all characteristic (Fig. 17).

The family Ichthyophthiriidæ has the oral orifice in the midst of an adhesive disc, and the cilia of the oral region are setose and radiate internally. The species of the only genus is parasitic on trout and salmon and the loach. The contractile vesicles in the sub-globose or ovate body are numerous, and its endoplast is curved. Length, $\frac{1}{150}$th of an inch (Fig. 14).

The family Colepidæ contains ovate-shaped animalcules which have an indurated cuticle, and the oral aperture terminal. *Coleps hirtus* is a good example, and it will be noticed that the surface is furrowed, so as to present the appearance of being divided into numerous equal quadrangular spaces. These are indurated, and the intervening furrows are soft and ciliated. The mouth is at one end, and the cilia near it are larger than the others, and the anus is at the opposite end. These Colepidæ divide transversely, and *Coleps hirtus*, which is from $\frac{1}{400}$th to $\frac{1}{500}$th of an inch long, has three spinous processes at its nether end. It is a common species, living in pond water amongst confervæ. It is a voracious animalcule, and it may be seen in numbers in the neighbourhood of any dead animal or vegetable matters. These it takes in with its cilia, which form currents mouthwards, and it may distend its body considerably (Fig. 13).

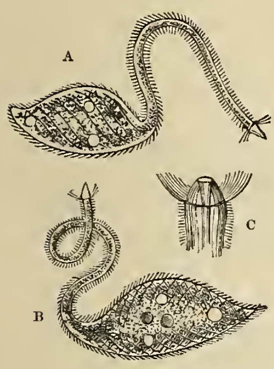


Fig. 17.—A, B, TRACHELOCERCA OLOR.
C, cilia of the mouth

During the process of natural fission, the extremities retain their usual aspect, but the newly-developed central area, where separation is to occur, is smooth, and thus, after division, one part of each Coleps is smooth, and the other like that of the parent.

There is a group of four families of these Holotricha which is characterised by the presence of a portion of the cuticle or ectoplasm formed into a flap, which may or may not vibrate. The Ophryoglenidæ have the oral aperture situated at the bottom of a distinct depression in the body, within which is a vibratile flap or membrane. The genus Ophryoglena has the family character, and the genus Trichoda resembles an Enchelys in shape, but the mouth is led to by an ovate furrow, and from its inner wall starts a vibratile flap. This genus is common in putrid infusions with the Enchelys already mentioned. A second family (the Pleuronemidæ) has the membrane extending in front of the oral furrow in a hood-like manner, and it is not vibratile. The third family (the Lembidæ) has long, vigorously-swimming, worm-shaped animalcules, and the membrane forms a long crest-like border to that furrowed part of the under surface of the body which extends from the front, backwards, to the oral aperture. It has large cilia along its inner border. *Lembus velifer* has a long spike-shaped body, narrow in front, thicker behind, where the contractile vesicle is seen, and the body is covered with long cilia. Beneath, in front, is the large membraniform expansion like a fin, broadest in front. The front part of the body is elastic, and can change its shape, and the hinder part is rounded. They increase by cross and longitudinal division (Fig. 9).

The last family of the group has been discovered by Leidy, and its species are most extraordinary looking things, and lead very remarkable lives. They are freely moving, but rarely swimming animalcules, their movements being chiefly of a twisting and writhing kind. The shape is more or less elongate and spindle-shaped, and the cuticle is entirely ciliate. Sometimes there are undulating membranes on it. They occur as parasites within the intestine of the American White Ant (*Termes flavipes*). Leidy found some white ants which had their intestines, as seen through their translucent abdomen, considerably distended with a brown substance, which consisted mainly of these parasites,

decayed wood, and the filaments of one of the Algæ. *Trichonomorpha agilis* (Fig. 18) has the cilia various in length, forming three or four distinct sets, and one of them is very long. The body is more or less separable into a smaller ovate head-like portion and a larger and inflated body. The oral aperture is indistinct, and is a rounded pore at the summit of the head, whence there passes backwards a tube to the endoplasm of the posterior part. There is a granular nucleus in the centre, but no contractile vesicle has been observed. The movements consist of an incessant retraction or shortening and bending to and fro of the head-like anterior region, accompanied by the rapid waving and swelling outwards of the long cilia. It is very possible that these animals may belong to another class of animals altogether.

Fig. 18.—TRICHONOMORPHA AGILIS. (*Leidy*)

The last group of the Holotrichous Ciliata contains one family, the Opalinidæ, whose species are parasitic within the intestines of Amphibia and Invertebrata. The genus Opalina is very characteristic, and its species are mouthless, free-swimming, and they may be ovate or elongate in shape. The cilia cover the cuticle throughout, and this is striated. There are no extraordinary organs of prehension, and the spherical or oval endoplast is single in young individuals. It breaks up by repeated divisions, as growth proceeds, into innumerable minute rounded bodies, each having a clear peripheral zone and endoplastule. There is no contractile vesicle. *Opalina ranarum*, $\frac{1}{30}$th to $\frac{1}{45}$th of an inch long, is found in the intestines and rectum of the common frog and toad. Its body is usually ovate, flattened, evenly rounded posteriorly, and the anterior part is bluntly pointed. The minute embryos contained in cysts (Fig. 19, G) are found in the rectum and excreta of frogs in the early part of the year. They get into the water where tadpoles are developing, and are eaten by them. The cyst has its wall broken or dissolved in the digestive canal of the tadpole, and the embryo is set free. At this stage the young Opalina is long, egg-shaped, covered with cilia, and has a large endoplast and a number of corpuscles in the endoplasm (Fig. 19, H). After a short interval, the body becomes longer, slightly curved in front, and the endoplast becomes divided into two or four equal spheroidal portions (Fig. 19, I). After a while the pointed end becomes rounded, and the normal shape is attained (Fig. 19, A). When fully grown the animalcule begins to increase in numbers by fission, and the first division takes place obliquely (Fig. 19, B), so that one individual has a pointed posterior end, and the other a rounded-off one. The separated moieties subdivide over and over again, first obliquely and then transversely (Fig. 19, C, D), until at last the pieces are not more than $\frac{1}{500}$th to $\frac{1}{700}$th of an inch in length. These are long, oval in shape (Fig. 19, F), and soon become languid in their movements, and contract to a spherical shape, diminishing in bulk and becoming encysted. The endoplasts included in the animal at the encystment unite in one, after the swallowing by the tadpole, and this one is carried out with the young free-swimmer.

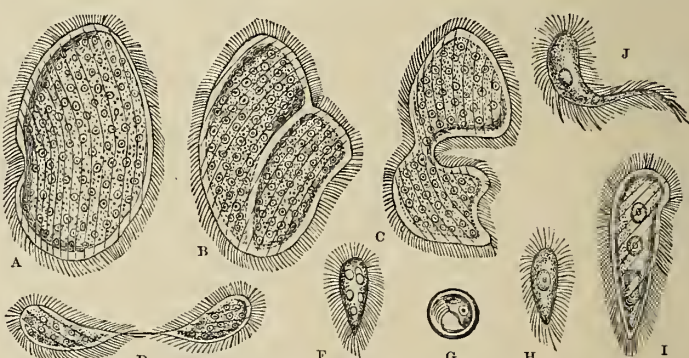


Fig. 19.—OPALINA RANARUM. (*After Zeller and Englemann.*)
A. Adult. B. Oblique division. C, Transverse fission. D. Fission. F, Last stage before encystment. G, H, I, J, Stages of growth of young.

Another genus of the Opalinidæ is Anoplophrya, and its species are parasitic within the intestinal organs of many Invertebrata. The type is *Anoplophrya prolifera* (Fig. 20), which is found in the intestinal cavities of various marine Annelids on the Norwegian coast. It is mouthless, long, widest in front, striated longitudinally, and ciliated along the striæ. The endoplast is in the axis, is long and sub-cylindrical, and the contractile vesicles are numerous,

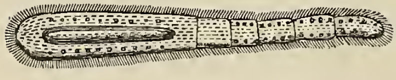


Fig. 20.—ANOPLOPHRYA PROLIFERA. (*After Claparède and Lachmann.*)

and in two long rows. These animalcules increase by several divisions across the body, and their length is $\frac{1}{20}$th of an inch.

SUB-ORDER HETEROTRICHA.

These Ciliata are free swimming or attached, naked or loricate, and the cilia form two widely distinct systems; those of the general surface being short, and those of the oral region large and like cirri. These oral cilia are either linear in their arrangement, or form more or less spiral or circular series. The cortical layers are well developed, and sometimes contain parallel muscular fibrillæ.

The largest Infusoria are amongst this sub-order, which may be divided into a family, the Bursariadæ (Fig. 21), which has the cilia near the mouth confined to the left border of the mouth groove, and into six other families which have the mouth cilia in a spiral or circular series round the aperture. The first family of this second group has free-swimming animalcules, and the fringe of cilia around the oral aperture is confined to the ventral surface, and the anal orifice is behind and at the end. *Spirostomum ambiguum* is the type of the family, and is one of the largest animalcules, measuring $\frac{1}{6}$th to $\frac{1}{8}$th of an inch in length, and being visible to the naked eye, "gleaming," Saville Kent remarks, "like golden threads in the sunlight" (Fig. 22).

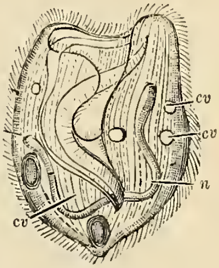


Fig. 21. — BURSARIA TRUNCATELLA. (*After Stein.*) *cv*, Contractile vesicle; *n*, endoplast curved.

When they are placed in clean water off the duckweed on which they like to move, the body is long and filiform, has a tendency to twist itself and untwist, and the eye is struck by the long contractile vesicle which occupies much of the hinder part of the body, and by the endoplast, which is long and moniliform. The slit for the mouth is surrounded by cilia.

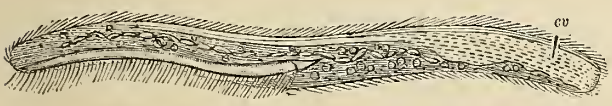


Fig. 22.—SPIROSTOMUM AMBIGUUM. (*After Stein.*) *cv*, contractile vesicle.

Another member of the family is *Condylostoma patens*, found in sea water, and $\frac{1}{45}$th to $\frac{1}{72}$nd of an inch in length. Its endoplast is moniliform and long, and the anterior border of the body is rounded off, and flat in front, and the mouth groove is an angular excavation occupying much of the ventral surface. There is an undulating membrane extending over the whole length of the right side of the peristome border. The contractile vesicle is canal-like, and breaks up into minor spaces (Fig. 12).

A most important family has the trumpet-shaped animalcules in it, which are usually found adherent by their narrow bases, and often freely swimming. The broad trumpet opening of these Stentoridæ is the region around the mouth, and the left-hand extremity is turned in spirally, forming a funnel-shaped groove which leads to the mouth. The right-hand limb is usually raised higher than the opposite one, and all the cilia around the mouth are large and strong. The cilia of the rest of the surface are small, and arranged in regular longitudinal rows, and there are occasional setæ. The endoplast is canal-like, and the contractile vesicle is an anterior circular dilatation, which gives off an annular branch that underlies the circumference of the peristome.

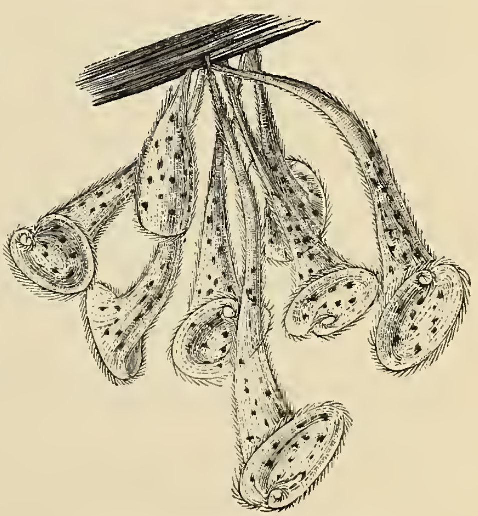


Fig. 23.—STENTOR POLYMORPHUS.

Stentor polymorphus (Fig. 23) is a large form, and the colour is produced by the presence of rich green chlorophyll granules. Its endoplast is moniliform, and the whole trumpet is $\frac{1}{20}$th of an inch long. It lives in groups, and the stems of all are immersed in a mucus which they secrete and hold on by. When swimming the shape is altered, and may be pear-shaped or top-shaped, and they fix them-

selves at pleasure. They increase in numbers by oblique fission, and a rudimentary mouth fringe appears, and only in the part of the body which will require it after division. They live in standing water among living and dead vegetation. One of the genus has blue colouring matter, and another, in addition to its green chlorophyll, has spots of a brilliant scarlet, and a third is black. The species of the genus Folliculina secretes a lorica, and the peristome opening occupies the end of the projecting part of the animalcule (Fig. 24). *Tintinnus lagenula* is a type of a family of this sub-order (Fig. 7).

SUB-ORDER PERITRICHA.

These Ciliata have the body smooth, except where there is a circular or spiral wreath of cilia in front. Sometimes there is a second encircling wreath which may be at the posterior part of the body, or at the middle. When the anterior circlet of cilia assumes a spiral form the right limb of the part around the mouth is mostly band-like and long. These animalcules may be free swimming or attached in colonies, and in this case often forming branching growths. They multiply by transverse and longitudinal fission, and by conjugation.

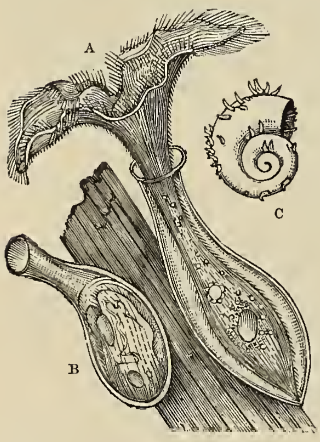


Fig. 24.—FOLLICULINA AMPULLA. (*Modified after Stein.*)
A, Protruding from, and B, contracted in lorica; C, Spirorbis shell with animalcules attached.

This very important sub-order is well divided into those families which are free swimming, and those which are sedentary or attached.

There are seven families of free swimmers, and in the first, containing the genus Torquatella, the cilia around the mouth are replaced by a vibratile collar. The second family has the animalcules protected by a silicious covering or lorica, and the third has no lorica, and there are retractile tentacules with the fringe of cilia in the front.

Halteria grandinella (Fig. 25) is the type of the fourth family, and is a free-swimming globular animalcule, and it has the oral aperture at one end, and associated with a spiral or sub-circular wreath of large cirrate cilia. There is a zone of long hair-like setæ around the body equatorially, and they enable the creature to jump in a most extraordinary manner. They roll themselves about, and suddenly leap backwards on to one side. There is a contractile vesicle and a spherical endoplast. The length is from $\frac{1}{860}$th to $\frac{1}{1500}$th of an inch, and it inhabits pond water.

Another family has the animalcules pear-shaped; the mouth is lateral, and there is a fringe of cilia around the body equatorially. *Urocentrum turbo* (Fig. 26) is the example, and the zones of cilia are in front, and equatorially, there being a terminal style, which is flexible, and enables the animalcule to adhere. The endoplast and contractile vesicle are very visible. It rotates like a top in the water, and moves forwards and backwards, and fixes itself, and spins backwards and forwards, so as to twist and untwist its stalk. The contractile vesicle has two or four sinuses, and the coutraction expels the water visibly externally. They increase by transverse division.

In the family Urceolaridæ the wreath of cilia is near the adhesive disc-like posterior end, and the seventh family is peculiarised by its terminal setæ, and a spinal adoral wreath of cilia.

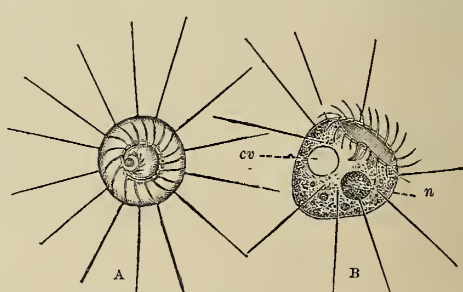


Fig. 25.—HALTERIA GRANDINELLA.
A, Ventral, B, lateral, aspect; *cv*, contractile vesicle; *n*, nucleus.

The family which contains the genus Dictyocysta is characterised by the possession of a beautiful helmet-shaped or bell-shaped silicious lorica, which is usually perforated so as to resemble a fine lacework. The species are from salt waters, are free swimmers in the Mediterranean and south-west coast of England. In their tests they closely resemble Polycistinæ.

The family Vorticellidæ comprehends the Peritricha which are fixed during the greater part of their lives, and which are only temporarily free swimming. These are the "Bell Animalcules"

which form colonies, and the commonest of which have their stalks contracting, often in a corkscrew shape, the end of the bell being provided with a circle of long active cilia. Occasionally they may be seen freely swimming, and then there is a second circlet of cilia at the tail end; but they soon settle down, become attached, and grow a stalk, the lower circlet of cilia disappearing. Very often the group of these stalked Vorticellidæ are so large that they are visible to the naked eye, and hence they were amongst the first animalculæ described. There are numerous genera, arranged in sub-families, and some have no stalk and others have it, and they may be solitary or social, arranged in branching groups on a common stem or immersed in mucus. The animalcules are highly contractile, and vary in shape from that of a long egg to sub-cylindrical, or a long or broad bell shape (Fig. 11). The free end of the bell consists of an outer raised border, sometimes but not always ciliated, and this closes the opening like a sphincter when the animalcule shuts up. As it reopens this peristome is seen to environ a spiral membrane with a circle of cilia on its free surface, and this projects beyond the peristome and the cilia produce very forcible currents in the water. On one side the circle is incomplete, and leads to a furrow which is often prolonged backwards on the body to a canal-like opening to the mouth. The movements of the cilia cause the particles of food to take the direction of this furrow, which has often a long solitary cilium at its free end. The spiral part, or disc, can be protruded or retracted. The endoplast is band-like and large, and the contractile vesicle is single, spherical, and is placed close to the anal aperture, which is distinct near the furrow. The stalk, when it exists in its highest degree of perfection, has an outer cuticle continuous with that of the body, and an inner spiral tissue more or less longitudinally fibrous, which is continuous with the myophan layer of the hinder part of the bell. Contraction produces spiral winding of the stem in some species, and a slow unwinding happens subsequently.

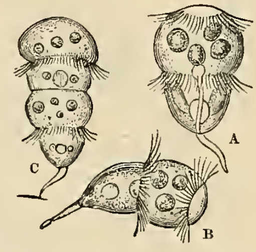


Fig. 26.—A, B, UROCENTRUM TURBO; C, TRANSVERSE FISSION.

The animalcules rarely divide by transverse and usually by longitudinal fission, which takes place through the endoplast and contractile vesicle. The offshoot grows a circle of cilia close to the stalk, which does not divide, and after a while it escapes as a free swimmer. In some species there is a free-swimming and small animalcule, which finally settles on the side of one of the larger fixed individuals, and either penetration occurs or the contents of the smaller pass into the larger. The endoplast subsequently develops a host of germs, which escape and become like the parents with growth.

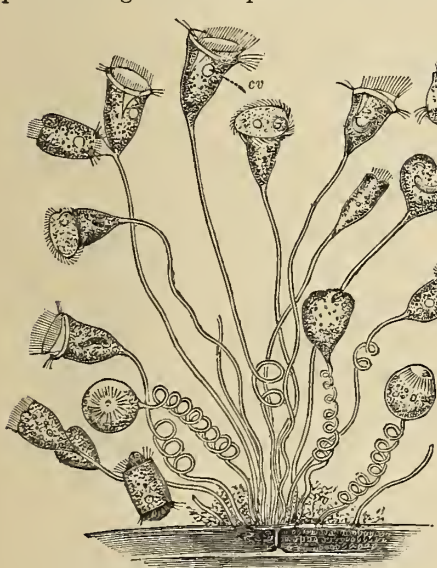


Fig. 27.—VORTICELLA NEBULIFERA.
cv, Contractile vesicle.

In the sub-family Vorticellina the animalcules are naked, long, without a stem, and are sessile on substances; some have a distinct sucker, by which they cling on, mostly to moving invertebrata and sometimes to weeds in fresh water. One of the genera (Spirochona) has solitary individuals, and the peristome is developed into a spiral funnel, and in Stylochona there is a rigid pedicle or stem instead of a sucker at the tail end. Then there is a genus with all the characters of the genus Vorticella, but the stem is rigid and uncontractile, and the animals are solitary; and in the genus Pyxidium the solitary animalcules have a rigid stem and a ciliary disc projecting beyond the peristome. These forms lead up to Vorticella as a genus, which is the type of the family. *Vorticella nebulifera* (Fig. 27) is common in ponds attached to duckweed or other water plants, and is a very beautiful object under the microscope. The bell-shaped body of each individual is about $\frac{1}{300}$th of an inch in length, and is attached to a long

flexible stem, which is for a while extended to the utmost, the cilia of the disc and peristome being in full action. Suddenly the stem contracts, becomes spiral, and the body closes slightly and bends on its stalk. Then the oral end opens, the cilia move again, and the stalk is drawn out to the utmost. This goes on very irregularly in a colony of a score or more of individuals, so that whilst some are contracted others are in full play. The currents in the water, produced by the ciliary fringes, are considerable and move much disintegrated matter into the oral grooves. The phenomena of fission and conjugation may be seen in the same colony at the same time, and every now and then a bud moves off by means of its hinder circle of cilia.

Fig. 28.—A, ZOOTHAMNIUM NIVEUM (*Saville Kent*); B, SINGLE ANIMALCULE, MORE HIGHLY MAGNIFIED; C, EPISTYLIS UMBILICATA; D, BRANCHLET OF CARCHESIUM POLYPINUM; E, AN EPISTYLIS GROWING ON A CYCLOPS.

In the genus Carchesium, which belongs to this group, a host of animalcules are on branchlets springing from a common stem. Usually the bell-shaped bodies are on one side of their branchlet, and each one has a stem continuous with the branch and main stem. A muscular tissue resembling that of Vorticella is in the stem and its prolongations, but it is discontinuous, so that each body can contract without the others, and each branchlet can do the same irrespectively of others, and the whole may contract with the primary stem and form a small globular mulberry-looking mass.

The species live in fresh and sometimes in salt water, and the whole colony originates in the fission of one individual and its stalk, and is fully developed by the successive longitudinal fissions of body after body (Fig. 28, D).

The genus Zoothamnium has the animalcules like those of Vorticella, but often dissimilar in shape and of two sizes, and they are placed at the end of a branching, highly contractile stem. The internal muscle of the stem is continuous throughout. This is not spiral in its construction, so that the stem never forms a spiral during its contraction. In *Zoothamnium niveum*, which is a salt-water form, there are spherical animalcules of large size near the bases of the primary branches, and the smaller ones at the ends of branchlets are long bell-shaped (Fig. 28, A, B).

Another genus, Epistylis, with its animalcules closely resembling Vorticella, has them attached in numbers to a rigid, uncontractible, branching, tree-like stem, and the bodies are of the same size throughout. *Epistylis flavicans* forms slimy encrustations on water plants and on the sides of aquaria. Many species settle on small crustacea (Fig. 28, C, E).

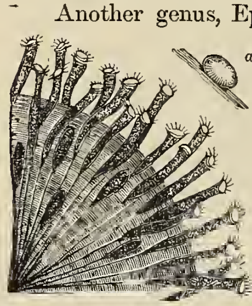


Fig. 30.—OPHRYDIUM EICHHORNII. (*After Saville Kent.*) *a*, *O. sessile*, natural size.

The next sub-family includes animalcules which excrete hard sheaths as loricæ and live within them. The genus Pyxicola, whose species live for the most part in salt water, has an erect lorica or a stem of attachment, and a horny plate on the body beneath the border of the peristome. This closes in the top of the lorica when the animal retreats. They inhabit fresh and brackish water (Fig. 29).


Fig. 29.—PYXICOLA PYXIDIFORMIS.

The last sub-family, the Ophrydinæ, contains Vorticella-like animalcules which excrete and inhabit a soft mucilaginous sheath or mass which may contain many.

Ophrydium Eichhornii (Fig. 30) is an example, and it forms attached gelatinous masses in which are numerous individuals, each with its slender pedicle. The body is long and narrow, and the whole is very elastic. They live in fresh water, attached to Anacharis, and about a hundred may be in a mass measuring $\frac{1}{80}$th of an inch. They increase by transverse as well as by longitudinal fission.

SUB-ORDER HYPOTRICHA.

These animalcules are free swimming, and the locomotive cilia are confined to the inferior or ventral surface, and are often modified into setæ and hooks. The superior surface is either smooth, or has some immobile setæ on it. The mouth and anus are ventral. Saville Kent subdivides this group into six families and forty-two genera. *Chlamydodon mnemosyne* is the type of one family, and it has a short, kidney-shaped body, the front being wide and the dorsal surface convex, and the ventral having a striated border. The cilia are the most conspicuous anteriorly, and they project as a fringe. The oral aperture has a bundle of rods in its membrane. The endoplast is single and ovate, and there are many contractile vesicles. It inhabits salt water (Fig. 31).

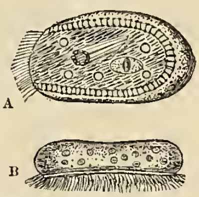


Fig. 31.—CHLAMYDODON MNEMOSYNE. A, Under, B, side view.

Another family, the Dysteriidæ, mostly inhabit salt water, and these free swimmers are mostly provided with a lorica either single or made up of two joined or detached valves like a small crustacean. The cilia are on the lower surface and the oral aperture leads to a canal, or pharynx, with a horny tube, or rods. The animalcules have a conspicuous tail-like style, or a group of setæ.

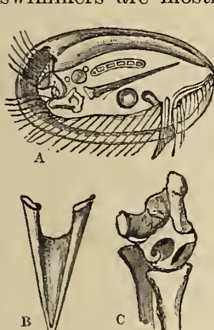


Fig. 32.—DYSTERIA ARMATA. (*After Huxley.*) A, Left side; B, C, pharyngeal apparatus.

Dysteria armata, a salt-water form, $\frac{1}{250}$th to $\frac{1}{350}$th of an inch in length, is remarkable for the anatomy of the pharynx. The oral fossa has a curved rod which terminates in fork-like teeth, and which is lost in the walls of the fossa. Then comes the armature of the pharynx, which consists of two portions—an anterior rounded mass in opposition with a much elongated styliform posterior portion. These animalcules live in swarms among the confervoid Algæ which coat the shells of limpets and periwinkles (Fig. 32).

The family Peritromidæ has the ventral surface finely ciliate, and there is a curve of powerful cirri around or near the mouth, and the pharynx is unarmed.

A host of flexible or persistent in shape animalcules, with front, ventral, and rear styles, and hooks and setæ at the margin, belong to the Oxytrichidæ. The common *Stylonychia mytilus* is an admirable example. It has a hard covering, or lorica, and the neighbourhood of the mouth has a great curve of long cilia on an undulating membrane. There are usually eight styles in front, five claw-like hooks on the ventral surface, and five straight anal styles. The marginal setæ form a border, and there are three long tail-like setæ. There are two endoplasts, sometimes divided, and a contractile vesicle. It inhabits fresh water, and the largest are $\frac{1}{72}$nd of an inch long (Fig. 8).

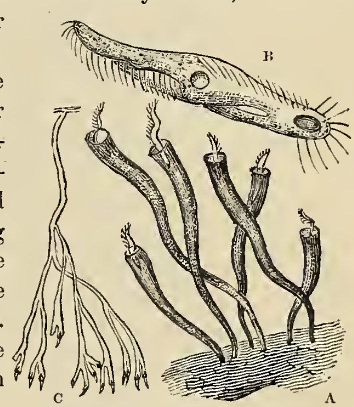


Fig. 33.—STICHOTRICHA REMEX. (*After Hudson.*) A, Animals in tubes; B, free animalcule; C, diagram of *Schizosiphon.*

Another species (*Stichotricha remex*, Fig. 33) has the cilia of the apex of the peristomial border very long, and the body is lanceolate, and inhabits a slender, brown tube, three or four times as long as the body, which projects from it with a twist.

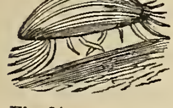


Fig. 34.—EUPLOTES CHARON.

Closely allied to these dwellers in separate tubes is a species (*Schizosiphon socialis*) which forms colonies that build up a branching tube. Another of this great family is *Uroleptus piscis*, and it is remarkable for its attenuated end, two endoplasts, and great curved ciliated peristome.

A family of the Hypotricha has no setæ along the margin, or they are rudimentary, but there is a lorica, and there are ventral and anal styles, or else hooks. In *Euplotes*

charon the dorsal surface of the body is ribbed, as it were, and there are seven frontal and three ventral styles, besides five posterior strong setæ (Fig. 34).

ORDER CILIO-FLAGELLATA.

The animalcules of this order are readily distinguished by their bodies being more or less ciliated, and by their having a long lash-like flagellum. The mouth is usually distinct. Saville Kent divides them into four families and sixteen genera, and the individuals are occasionally very numerous, producing the phosphorescent condition of the sea, and discolouring fresh and salt water. Most of the Cilio-flagellata, a type of which has already been noticed (pp. 356–7), are small, $\frac{1}{500}$th of an inch being the greatest length, but amongst the genus Ceratium there are some large forms, some reaching $\frac{1}{72}$th of an inch in length. They are found in fresh and in salt water; and, so far as is known, none are parasitic or sedentary; but during one of the reproductive phases encystment occurs, and a period of quiescence precedes the escape of the young. They are active swimmers as a rule, the lash-like flagellum (in rare instances there are two) enabling rapid and irregular motion easy, and the cilia produce ordinary movement. Fission occurs, but the reproductive phenomena have not been observed satisfactorily. Some of the Cilio-flagellata are naked, and others have a shell, or horny cuirass, which may be smooth or ornamented, and often prolonged into horn-like processes. Some of these loricæ have been preserved in the strata of the chalk, and are referred to the genus Ceratium. The general character of the group having been given already, it is only necessary to observe that the family Peridinidæ contains ten genera. In all there is a distinct ciliary girdle, and one flagellum. In a doubtful genus there are two of these organs. In some of the genera the ciliary girdle is central, in others eccentric, and in one it is terminal. Some genera have a cuirass, and many others are naked. Melodinium, already noticed (p. 356), is an example of a naked, and Ceratium of a cuirassed and horned genus. Peridinium has no horn-like processes, and the cuirass is facetted (Fig. 4, A–H).

The second family* has one vibratile flagellum, and one which is trailed, and the body changes in shape, like Amœba; and the third family† has the body clothed with long setose cilia, and a terminal flagellum, the body shape being persistent. A fourth family has a wreath-like crest or collar of cilia, and in the midst a flagellum, which may or may not be retractile;‡ and the last family,§ which links the order with that of the Ciliata, has a more or less perfect ciliary covering, and a flagellum. The colours differ, and there may or may not be a red spot in these families. Yellow, light-brown, green, pink, reddish-brown, vermilion, are common colours; and usually the endoplasm is transparent, and holds coloured matters in suspension. *Peridinium splendor-maris* of Naples is highly phosphorescent, and *P. sanguineum*, of salt-water pools and the sea-shore of India, is green when young, and with growth a number of oil globules is secreted within, and the green colour disappears, and a bright red tint comes on, just before encystment. The red colour of patches of the sea is due to this form, in many instances, and it is noteworthy that the presence of these animalcules renders water very disagreeable.

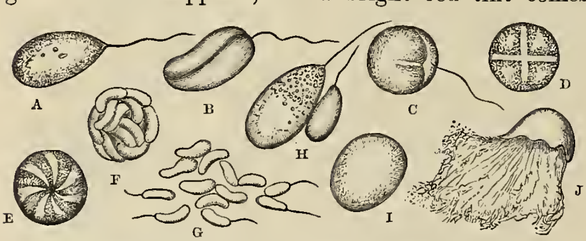


Fig. 35.—MONAS DALLINGERI. (*Saville Kent.*)

A, B, Adult; C, about to encyst; D, E, F, encystment—formation of spores which are liberated as monads; G, H, conjugation: I, encystment from conjugation; J, bursting of and liberation of spores (small).

ORDER FLAGELLATA.

These animalcules, generally very minute, have one or more long slender flagella; there are in some instances pseudopodia. The mouth may be doubtfully present, and food may be taken in at one spot, or anywhere. One or more contractile vesicles are almost invariably present. They increase by fission, or by breaking up of the endoplasm in the encysted state.

This definition explains how difficult it is to limit the lower Flagellata. It is possible that many of the so-called Flagellata are stages of plants, and indeed it seems impossible to draw a hard and

* *Heteromastigidæ* (Fig. 4, K). † *Mallomonadidæ* (Fig. 4, L). ‡ *Stephanomonadidæ* (Fig. 4, I).
§ *Trichonemidæ* (Fig. 4, J).

fast line where the animal and vegetable kingdoms branch off. Saville Kent has paid much attention to the order, and his descriptions and classification are excellent.

The Flagellata may be divided into three sub-orders: in the first there is no defined mouth, and the food may be taken in by any part of the body, and in the second the food is received in the

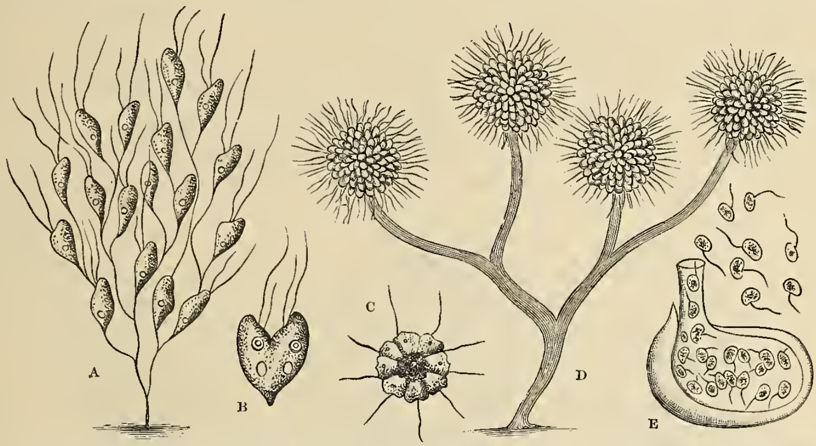


Fig. 36.—A, CLADONEMA LAXA. (*After Saville Kent.*) B, ANIMALCULE DIVIDING; C, ANTHOPHYSA VEGETANS, SWIMMING CLUSTER; D, ANTHOPHYSA VEGETANS, SHORT BRANCHING COLONY; E, SPOROCYST LIBERATING GERMS.

anterior region. A true opening for food exists in the third, which have a non-ciliated body with a flagellum. The sections of the first sub-order are the Trypanosomata, membranous organisms found in the blood of frogs and toads; the Rhizo-flagellata, which have amœbiform bodies and a flagellum; the Radio-flagellata, with or without a lorica, having a flagellum, and ray-like pseudopodia; and the Flagellata-Pantostomata proper, which have a flagellum and the food incepted anywhere. A host of genera belong to this sub-order and Monas may be represented by

Monas Dallingeri, $\frac{1}{4000}$th of an inch in length. It has one flagellum, which is flexible when young, and rigid towards the base in old specimens (Fig. 35).

Cercomonas has a caudal filament besides a flagellum (*Cercomonas typica*, Fig. 3).

The genus Cladonema, as the name implies, has a branching form, and the ovate bodies are attached to thread-like pedicles. There are two flagella (Fig. 36, A, B).

Anthophysa, a genus belonging to the same family, has small individuals $\frac{1}{3500}$th to $\frac{1}{4000}$th of an inch in length, and is in the form of clusters of fifty or sixty bodies at the ends of branching horny pedicles. These have contractile vesicles (Fig. 36, C, D).

Rhipidodendron splendidum (Fig. 37) is in masses, $\frac{1}{75}$th of an inch long, and has its bodies with two flagella. These are in a branching mass, like a fan in shape.

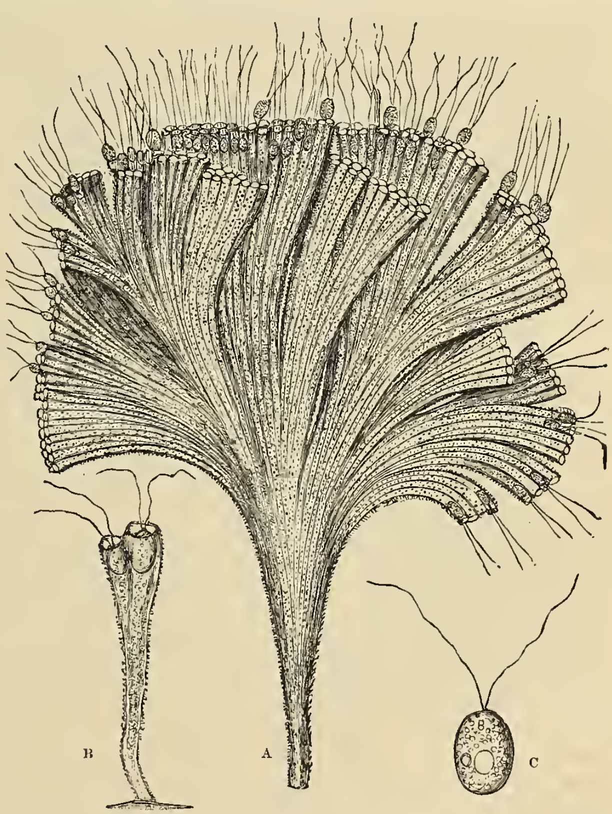


Fig. 37.—RHIPIDODENDRON SPLENDIDUM.
A, Colony; B, animalcule bifurcating; C. isolated monad.

The second sub-order comprehends Saville Kent's division of the collared monads (*Choano-flagellata*), with individuals varying from $\frac{1}{1000}$th to $\frac{1}{3000}$th of an inch in length, and some of which resemble the collared cells of sponges. It consists of three families. In the first the animalcules are naked, and either attached or free; the genera Monosiga, Codosiga, and Astrosiga are examples (Plate 72, Figs. 1—8). The forms of the second have a lorica, which may be solitary, as in Salpingæca and Lagenæca, and united in Polynæca (Plate 72, Figs. 9—18).

In the sub-order of the Flagellata, with a definite region for inception of food (Eustomata), the most interesting examples are the genera Noctiluca and Euglena. The first is one of the greatest producers of the phosphorescence of the sea.

Noctiluca miliaris, from $\frac{1}{20}$th to $\frac{1}{80}$th of an inch in diameter, is peach-shaped, and has a distinct meridional groove to its hyaline body. The mouth fossa is at one end of the groove, and has on one side a

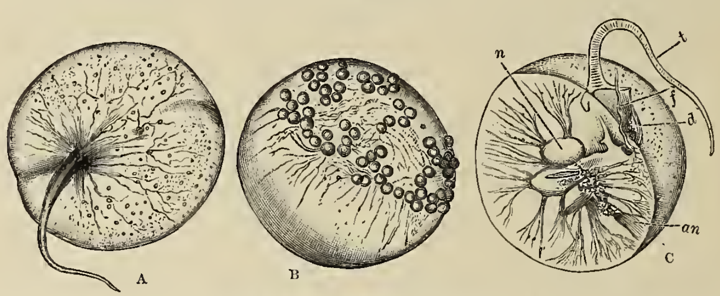


Fig. 38.—A, NOCTILUCA MILIARIS; B, SAME WITH BUDS (*from Photograph after Brooks*); C, IN SECTION. (*After Huxley.*)
n, nucleus; *f*, flagellum; *t*, tentacle; *d*, denticle; *an*, anus.

hard projecting ridge, close to one end of which arises the flagellum. Close by arises a tentacle about as long as the body, and there is a rod-like induration of the cuticle, extending in a straight line from the aboral extremity of the groove. The endoplast is oval. They exist in countless multitudes, and their greenish-silvery light is produced just underneath the cuticle in irregular flashes. They increase by transverse fission, accompanied by encystment and loss of the flagellum and tentacle. Under certain circumstances, the endoplast breaks up, and the protoplasmic contents of the cyst collect in one spot and form by division into many minute nodular masses. These cause the cuticle to rise, and finally they penetrate it and develop flagella. They become detached and swim as germs (Fig. 38).

Conjugation is also observed. The Noctilucæ live on minute floating Algæ, which may be seen amongst the vacuoles of the irregular endoplasm.

CLASSIFICATION.—CLASS INFUSORIA.

ORDER TENTACULIFERA	Sub-order	Suctoria. Actinaria.
" CILIATA	"	Holotricha. Heterotricha. Peritricha. Hypotricha.
" CILIO-FLAGELLATA.		
" FLAGELLATA	"	Pantostomata. Choano-flagellata. Eustomata.

The writings of Claparède and Lachmann, Stein and Huxley, have been used by the author; but his greatest obligations are to Mr. Saville Kent, whose excellent Manual of the Infusoria has been quoted largely, and often word for word.

P. MARTIN DUNCAN.

COLLARED MONADS (*Choano-flagellata*).

1, Monosiga fusiformis; 2, Codosiga alloides; 3, C. grossularia; 4, C. umbellata; 5, C cymosa; 6, C. botrytis; 7, Astrosiga disjuncta; 8, A. moniliformis; 9, Salpingæca marina; 10, S. ampulla; 11, S. Steinii; 12, S. napiformis; 13, S. Clarkii; 14, S. vaginicola; 15, S. cornutum; 16, S. tintinnabulum; 17, Lageuæca cuspidata; 18, Polynæca dichotoma—all highly magnified. (*Modified after Saville Kent and Stein.*)

INDEX TO POPULAR NAMES.

N.B.—*An asterisk prefixed to any page indicates that an illustration will be found on that page.*

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INDEX TO CLASSES, ORDERS, FAMILIES, GENERA, SPECIES, &c.

ABBREVIATIONS.—c., *class*; s.c., *sub-class*; o., *order*; s.o., *sub-order*; f., *family*; s.f., *sub-family*; g., *genus*.

*** An asterisk prefixed to a page denotes that an illustration will be found on that page.

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